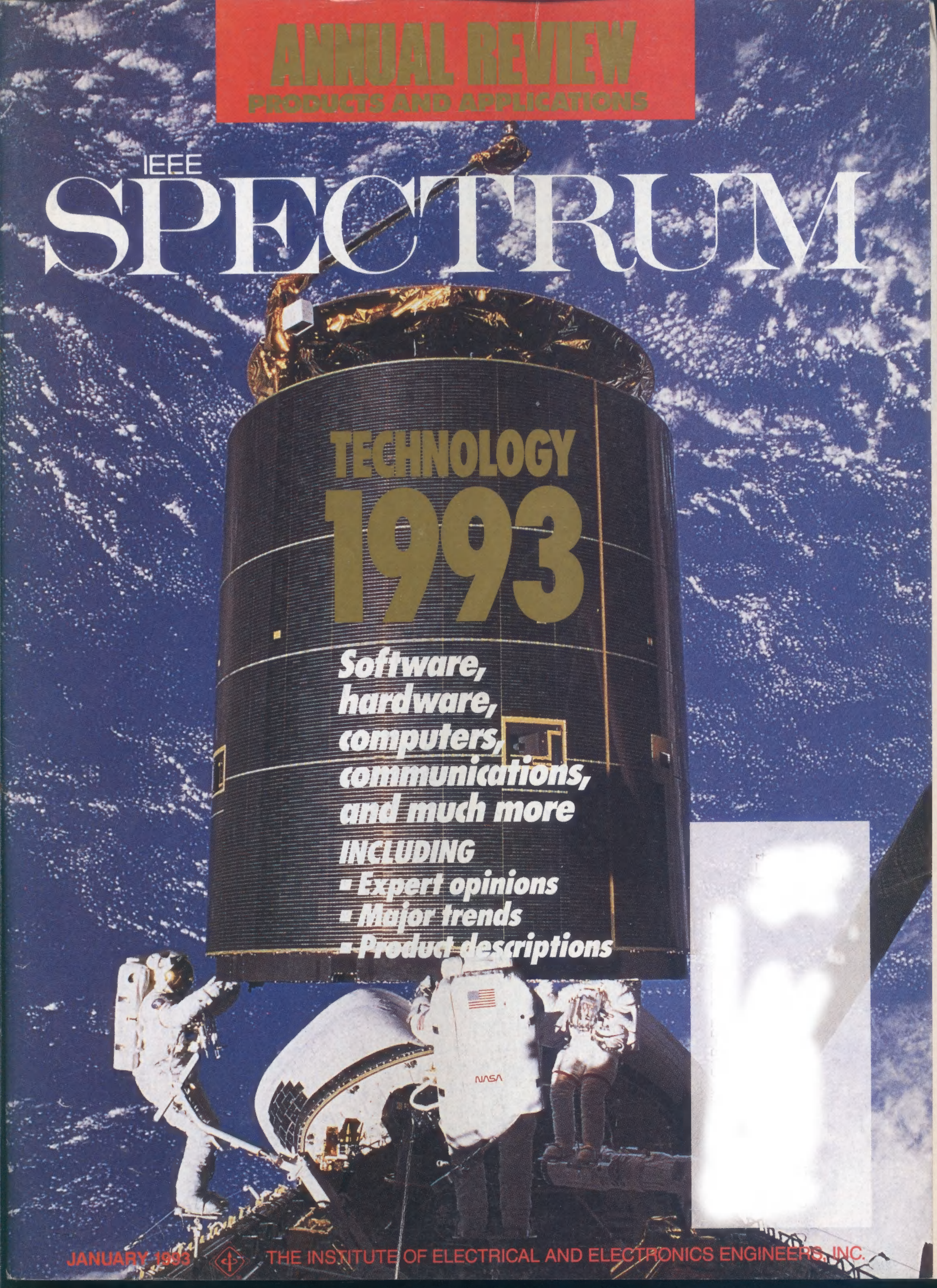
ANNUAL REVIEW
PRODUCTS AND APPLICATIONS

IEEE
SPECTRUM



TECHNOLOGY 1993

Software, hardware, computers, communications, and much more

INCLUDING
- Expert opinions
- Major trends
- Product descriptions

JANUARY 1993 THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

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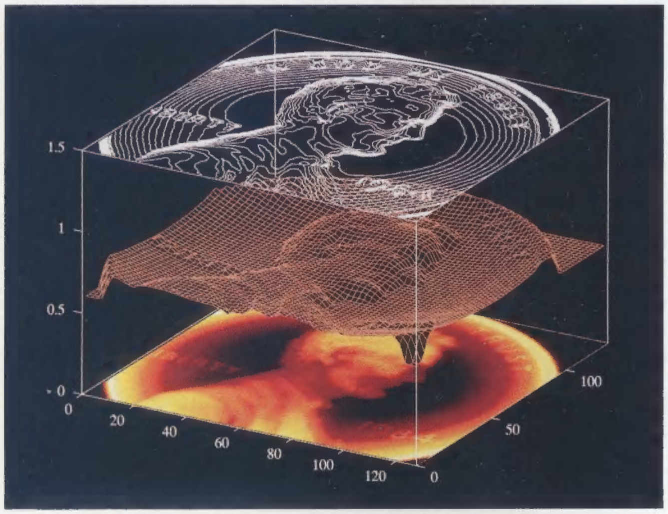

Three views of the surface height of a penny show user customizable object-oriented graphics in MATLAB 4.0. Data courtesy of NIST.

Combine advanced visualization with the powerful computation of MATLAB, and gain new insight into your most challenging problems.

The MathWorks introduces MATLAB 4.0

MATLAB 4.0 blends visualization techniques and numeric computation into a seamless interactive environment that redefines how you can solve complex problems. You can analyze data numerically and visually, simulate models and see the results immediately, or explore ideas and test them interactively.

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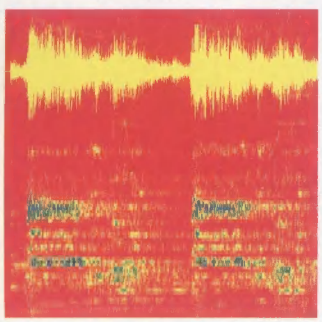

Spectrogram of Handel's Hallelujah Chorus, *computed and displayed with MATLAB 4.0 and the Signal Processing Toolbox.*

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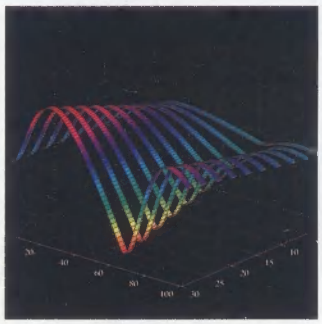

Frequency responses of a family of control systems, modeled, simulated and visualized in MATLAB 4.0.

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- *Chemometric Analysis*

Riemann surface of the complex cube root function shows the capability of MATLAB 4.0 for mathematical visualization.

MATLAB 4.0 is available now for Sun SPARCstations, and will soon ship for other standard MATLAB platforms including: 386/486 PCs, Macintosh, HP/Apollo, DECstation, VAX/VMS, IBM, Silicon Graphics, Convex, & Cray.

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Circle No. 16

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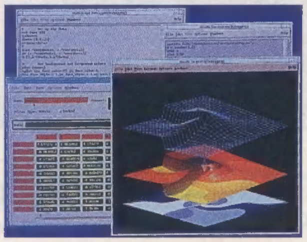

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Circle No. 7

Newslog

NOV 11. BCE Inc., the Montreal telecommunications group, announced that it would pay about US $725 million for a 20 percent share in **Mercury Communications Ltd.,** a subsidiary of London's **Cable & Wireless PLC.** The companies said the deal, the largest such stock purchase yet in European telecom services, would expand their global interests in the field and could bring more alliances.

NOV 11. IBM Corp. said it and **General Electric Co.'s NBC** television network would test a desktop service offering on-demand news and information in the metropolitan New York City area. The project will use technology from a third partner, **NuMedia Corp.,** Alexandria, Va. Customer companies will receive TV transmissions via satellite from NBC News, CNBC business-news cable, and possibly some of NBC's local affiliates.

NOV 19. Lockheed Corp., Calabasas, Calif., said its Space Operations Co. unit had received a 10-year contract, worth US $200 million a year, to manage the **Kennedy Space Center** in Cape Canaveral, Fla., for the National Aeronautics and Space Administration (NASA). Lockheed currently has 6200 people at the center working on space shuttle preparations, and plans to subcontract most of its new responsibilities to 3000 employees of **EG&G Inc.,** Wellesley, Mass., the center's former manager.

NOV 23. Lufthansa German Airlines, based in Cologne, said it had flown passengers on a 16-hour test flight of an **Airbus A340** from Frankfurt to Honolulu. The 12 500-km run set a record for a nonstop passenger flight from Europe. The wide-bodied, four-engined A340, which can carry 263 passengers, is expected to usher in an era of long-distance nonstop flights.

NOV 23. Martin Marietta Corp., Bethesda, Md., said it had agreed to buy the **Aerospace Division** of **General Electric Co.,** Fairfield, Conn., for $3 billion. The acquisition will make Martin Marietta the nation's largest supplier of high-technology military electronics, surpassing General Motors Corp.'s Hughes Division and Lockheed Corp. It also removes GE from businesses it has been in since World War I.

NOV 24. Microelectronics & Computer Technology Corp., Austin, Texas, said that, as a research company owned by 62 high-tech firms and the U.S. government, it had set up a working group to develop flat-panel displays for use in high-definition television and advanced personal computers. The nine-company group, called the Field Emission Display Consortium, plans to review the technology, finalize the design, then explore where the new displays should be assembled.

NOV 25. Representatives at a conference on the ozone layer, held in Copenhagen, Denmark, by the **United Nations,** announced that 87 countries had agreed to move up the deadline for halting production of chlorofluorocarbons (CFCs) to Jan. 1, 1996, from the year 2000. The delegates also set a timetable for eliminating hydrochlorofluorocarbons—interim substitutes for CFCs until permanent ones can be developed—lasting from 2004 to 2030.

NOV 30. British Telecommunications (BT) PLC, London, said it had awarded contracts worth a total $1.41 billion to Sweden's **Telefon AB L.M. Ericsson** and to **GPT Ltd.,** owned by the UK's General Electric Co. and Germany's Siemens AG. BT said the contracts, covering three years, were for new digital exchanges to modernize its telephone network.

DEC 1. AT&T & Co. said researchers at **Bell Laboratories,** Murray Hill, N.J., had isolated a compound from cantaloupes, n-butyl butyrate, which could replace the chemical trichloroethane used as a solvent in manufacturing ICs. To use the harmless, recyclable chemical, AT&T said it had developed a new manufacturing process that was to have been installed in AT&T's multichip module plants by early January.

DEC 1. Scientists at the **David Sarnoff Research Center,** Princeton, N.J., said they had developed new technology that allows computers to recognize and process pictures thousands of times faster than today's computers can. Called Smart Sensing, the technology selectively sorts through vast amounts of information in a visual scene and isolates its key characteristics—like movement, shapes, colors, letters, and face patterns. The advance could lead to self-guided robots, cars that recognize obstacles in their path, security systems that open doors only to an authorized face, and large but fast-of-access video information libraries. The center is owned by SRI International, Menlo Park, Calif.

DEC 2. A Federal District judge in San Jose, Calif., said that **Advanced Micro Devices Inc.,** Sunnyvale, Calif., did not have the right to copy and distribute products using the 486 microprocessor software of **Intel Corp.,** Santa Clara, Calif. Advanced Micro had claimed rights to use Intel's microcode under the terms of a 1976 licensing agreement between the two companies.

DEC 2. Tele-Communications Inc., Denver, Colo., announced that as early as 1994 it would equip its cable plant with digital compression technology, enabling a million of its cable customers to receive as many as 500 channels each. The commitment is the first national move to install the multichannel technology, which turns a standard cable channel into 10 channels.

DEC 3. Researchers at the **University of California School of Medicine at Davis** said they had completed a massive three-year study into health hazards in the semiconductor industry, confirming on a national basis that chemicals called glycol ethers have toxic side effects, such as miscarriages. The **Semiconductor Industry Association,** San Jose, Calif., which financed the $3.8 million study, said it would introduce new technology to minimize exposure to hazardous chemicals and would also recommend faster elimination of glycol ethers and the sharing of information about safe alternative technologies.

DEC 4. A Federal judge in Cincinnati, Ohio, awarded $13.4 million to **Chester L. Walsh,** a former **General Electric Co.** manager in Israel, for bringing forward evidence that GE defrauded the United States over the sale of military jet engines to Israel. The award was the largest ever in a Federal whistle-blower case.

DEC 4. France's Thomson CSF SA confirmed that it now owned the virtual reality patent rights held by a leader in the field, **VPL Research,** Foster City, Calif. VPL had pledged its patent portfolio as collateral for $1 million in loans made by Thomson, and had failed to repay. Industry experts said the loss is a blow to U.S. efforts to stay competitive in virtual reality, which also could help change the way engineers design by letting them see their creations more clearly before completing them.

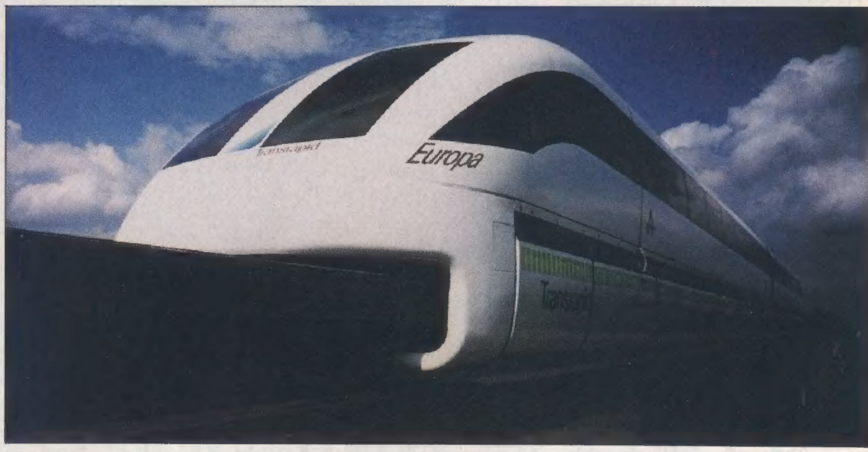
Preview:
JAN 13. NASA is to launch the **Space Shuttle Endeavour** from the Kennedy Space Center, Cape Canaveral, Fla., on a six-day mission with two key tasks: to deploy a Tracking Data Relay Satellite and to conduct spatial observations with a diffuse X-ray spectrometer.

COORDINATOR: Sally Cahur

JANUARY 1993 Volume 30 Number 1

IEEE SPECTRUM

TECHNOLOGY 1993



Maglev Transit Inc.

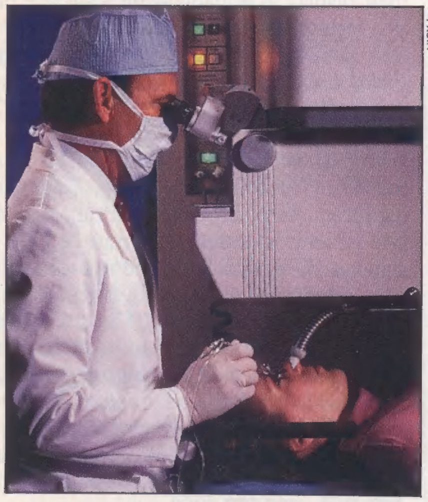
Transrapid magnetic levitation train such as this one will be purchased from Germany by Maglev Transit Inc., Orlando, Fla., for a demonstration at the Orlando International Airport. **68**

Apple Computer Inc.

Apple Computer Inc.'s Newton Personal Digital Assistant is capable of wired or wireless communications. **42**

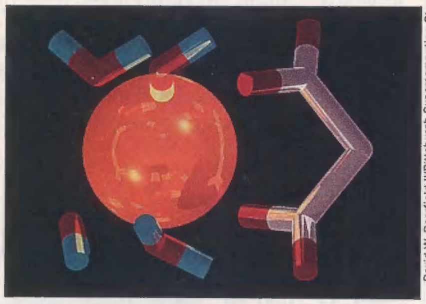
An engineer prepares the Exoatmospheric Reentry System (ERIS) interceptor for a flight test. **72**

Lockheed Missiles & Space Co.



VISX Inc.

Opthalmic surgeons use an excimer laser to sculpt the cornea of a nearsighted eye. **76**



David W. Deerfield II/Pittsburgh Supercomputing Ctr.

Calcium's role in blood clotting is simulated on a Cray Y-MP and DECstation 500/200. **34**

SPECTRAL LINES

Cover: Astronauts Richard J. Hieb, Thomas D. Akers, and Pierre J. Thuot gently grasp the Intelsat VI during the Space Shuttle Endeavour's first mission in May 1992. The nine-day mission rescued the wayward satellite and demonstrated a number of techniques needed for assembling Space Station Freedom. See p. 72. Photo: National Aeronautics and Space Administration.

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Forum

A desire for objectivity

The authors of "Diversity in the high-tech workplace" [June, p. 24] write ". . .there is not more overt evidence of discrimination or exclusion for 'new' groups in R&D. . . ." I fail to understand why, instead of leaving the "evidence" to an intuitive stipulation, the authors could not present a more quantitative picture as to how the managers' rating differs over a population having other parameters the same.

For example, they could have gathered some data on how the managers' responses vary over the individuals (given other "objective parameters" such as the same qualifications, skills, and accomplishments). Such responses could be with respect to the dimensions already presented in the article, and perhaps also with respect to the selection process, which might be relatively more difficult.

If one is really motivated to investigate the reality, there are other avenues as well. For example, other qualifications being the same, is there any prejudice displayed by a hiring manager in evaluating a candidate once he or she hears the candidate speaking with an accent (particularly a non-European accent)? Such a survey, although it would have to be done indirectly, nevertheless is feasible.

Javaid Aslam
Amherst, N.Y.

Speed and safety

As president of the National Motorists Association, I believe that "Improving on police radar" [July, p. 38], while reasonably accurate from a technical standpoint, missed the mark on public policy implications.

Speed enforcement policy and practices in the United States are largely based on myths and the self-serving objectives of vested interests. Finding cause-and-effect relationships, or even correlations, between speed enforcement and highway safety is a fruitless exercise.

The electronics war between motorists and enforcement agencies is the product of a 40-year campaign based on the premise that "speed kills." Reckless, inconsiderate, incompetent, and impaired driving causes accidents. These acts are not synonymous with exceeding an arbitrary, unscientifically established speed limit.

The overwhelming number of motor vehicle accidents occur on roads posted at or below 40 miles per hour (about 65 km/h). Only 1 percent of all motor vehicle accidents occur on highways posted at 65 mph, even though these highways carry over 10 percent of all vehicle traffic (Federal Accident Reporting System, U.S. Department of Transportation).

We would not need to concern ourselves with "Star Wars" speed-monitoring technology if the United States had 85th percentile speed limits, as recommended by traffic engineers. [The 85th-percentile speed for a particular road is the speed at or below which 85 percent of the vehicles actually travel on that road. Experience shows that most accidents involve vehicles traveling significantly above or below that speed.] The truly dangerous drivers would be readily obvious. The rest of us would be free to go about our daily affairs in a safe and responsible fashion.

James J. Baxter
Dane, Wis.

Torque talk

In "Pursuing efficiency" [November, pp. 22-24, 93], the author uses the phrase "42.5 kg-m of torque." Torque is the product of tangential force and radial distance; kilograms is a unit of mass, not force. I am not aware of any significance of the product of mass and radial distance, although some people might confuse it with moment of inertia, which can be expressed in units of kg-m^2 or momentum in units of kg-m/s.

This all too common gross error of trying to express torque in kg-m no doubt comes from the frequent confusion between pounds force and pounds weight. Torque is expressed in obsolete English units of lb-ft, but the conversion to proper SI units is pounds force to newtons and feet to meters, with the correct result of torque in newton-meters.

David W. Knudsen
Gorham, Maine

Reader Knudsen is right. Torque should indeed be expressed in newton-meters, and we erred in expressing it in kilogram-meters.

For the record, each of the Iza's four in-wheel motors can develop a maximum torque of 416.8 N-m. —Ed.

Software report addenda

The table "Electromagnetic design and simulation" [November, p. 53], should have included the following two entries:

• From Vector Fields Inc., a three-part package for electro- and magnetostatics, eddy currents, steady state and transient calculations. The parts are Opera, a pre- and postprocessor; Tosca, a three-dimensional solver; and Elektra, a 3-D solver with eddy currents. The package runs on VAX, DECstation, HP 9000/700, HP Apollo, IBM RS/6000, Intergraph 6000, Sun 4/Sparcstation, and Cray platforms. Operating systems used are VMS, Ultrix, HP-UX, Domain OS, AIX 3.1, CLIX 3.1, Sun OS, Unicos. The most significant new features are 2-D and 3-D static, steady-state or transient solutions, and the calculation of functions and their display as a mapping on a surface or as a histogram. A new PC version is available for 2-D calculations. *Contact: Vector Fields Inc., 1700 N. Farnsworth Ave., Aurora, Ill. 60505; 708-851-1734; fax, 708-851-2106.*

• From Hewlett-Packard Co., the HP High-frequency Structure Simulator. Used for high-frequency analysis of arbitrary 2- and 3-D structures, the package runs on DECstations, HP Apollo, IBM, and Sun workstations. Operating systems used are Ultrix, HP-UX, AIX, and Solaris. The package's most significant features are s-parameter calculations, animated electromagnetic field plots, and full loss analysis. *Contact: Hewlett-Packard Co., High-frequency Design Solutions, M/S 4US-K, 1400 Fountaingrove Parkway, Santa Rosa, Calif. 95403, 707-577-1400; fax, 707-577-5260.*

In the left column on p. 90 of the November issue, add the following address: *Techni-Soft, Box 2525, Livermore, Calif. 94550, 510-443-7213.* The company markets the SIGX 2.0 package listed in the table "Data acquisition, analysis, display and technical reporting software" on p. 70. *—Ed.*

Correction

On p. 74 of the November issue, the last full sentence in the third column should read: A student's version of Waterloo Maple Software's Maple V, R1 package is available for $99. *—Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum;* on the policies and operations of the IEEE; and on technical, economic, or social matters of interest to the electrical and electronics engineering profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial issues. Contact: Forum, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017, U.S.A.; fax, 212-705-7453. The compmail address is ieeespectrum. The computer bulletin board number is 212-705-7308 and the password is SPECTRUM; for more information, call 212-705-7305 and ask for the Author's Guide.

Books

A brief history of presidential science advising

M. Granger Morgan

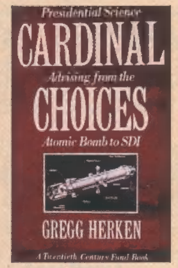
This is a history of the past 50 years of key defense-related scientific and technical advice to U.S. presidents. It is the most concise history of presidential science advising yet written and despite its narrow focus, will almost certainly become a standard reference for students of U.S. science and technology policy.

Nonetheless, because it concentrates on nuclear weapons and closely related defense issues, it gives a somewhat unbalanced and incomplete picture that may mislead newcomers to this topic and frustrate more knowledgeable readers.

Mind you, the impression left is only slightly off balance. The activity of presidential science advising has in fact been heavily skewed toward military-nuclear issues. Reading this history from today's post–Cold War perspective, one cannot help but be dismayed by the enormous effort in nuclear and related matters that has absorbed much of the attention of our senior political leadership and our best scientific minds for roughly half a century.

However, this book has little or nothing for readers interested in comparing the relative magnitude of this nuclear-advisory effort with advice on more conventional defense issues and on such critical civilian matters as the choice of an air-traffic control system based on airborne transponders, the selection of geostationary orbits for communications satellites, and the decision not to build the civilian supersonic transport.

Cardinal Choices: Presidential Science Advising from the Atomic Bomb to SDI.
Herken, Gregg, Oxford University Press, 1992, 317 pp., $24.95.



The book is divided into three parts. The first four chapters deal with World War II and the immediate postwar period. Readers pressed for time may want to skip these chapters since more complete treatments of the same material can be found in Daniel Kevles' *The Physicists*, Vannevar Bush's *Pieces of the Action*, and Richard Rhodes's *The Making of the Atomic Bomb*.

The second part consists of three chapters devoted largely to the Eisenhower years. These chapters, along with the first several chapters of the third part, are an excellent historical account and the most valuable part of the book. They deserve a careful reading by anyone interested in U.S. science and technology policy.

The two middle chapters in the third part describe the demise of the science advisory apparatus in the White House during the Nixon administration and its subsequent reassembly, in rather different form, during the Carter and Reagan years.

The short final chapter titled ''The present and future of presidential science advising'' is analytical and philosophical. Better discussions can be found in a number of the essays in William Golden's *Science and Technology Advice to the President, Congress, and*

(Continued on p.12)

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A brief history of presidential science advising

M. Granger Morgan

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Nonetheles… nuclear weapo… issues, it give… incomplete pi… comers to th… knowledgeabl…

Calendar

Meetings, Conferences and Conventions

JANUARY 1993

International Workshop on Modeling Analysis and Simulation of Computer and Telecommunication Systems (C); Jan. 17–20; Hyatt Regency Hotel, San Diego, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Winter Workshop on Nonlinear Digital Signal Processing (CAS et al.); Jan. 17–20; Murikka-Opisto, Tampere, Finland; Petri Haavisto, Signal Processing Laboratory, Tampere University of Technology, Box 553, 33101 Tampere, Finland; (358+31) 161 849; fax, (358+31) 161 857.

International Symposium on Information Theory (IT); Jan. 18–22; Hilton Palacio del Rio, San Antonio, Texas; Galen H. Sasaki, Department of Electrical and Computer Engineering, Engineering Science Building, University of Texas at Austin, Austin, Texas 78712-1084; 512-471-6734.

International Conference on Wafer Scale Integration (C, CHMT); Jan. 20–22; Fairmont Hotel, San Francisco; R. Mike Lea, Brunel University, Uxbridge, England UB8 3PH; (44+895) 203 221.

Ultrafast Electronics and Optoelectronics Topical Meeting (ED); Jan. 25–27; Hyatt at Fisherman's Wharf, San Francisco; Optical Society of America, 2010 Massachusetts Ave., N.W., Washington, D.C. 20036; 202-223-0920; fax, 202-416-6100.

Annual Reliability and Maintainability Symposium—RAMS (R); Jan. 26–28; Westin Peachtree Hotel, Atlanta, Ga.; V.R. Monshaw, Consulting Services, 1768 Lark Lane, Cherry Hill, N.J. 08003; 609-428-2342.

Aerospace Applications Conference (South Bay Harbor Section); Jan.31–Feb.5; The Ranch at Steamboat, Steamboat Springs, Colo.; Sohrab Mobasser, Jet Propulsion Laboratory MS 185-105, 4800 Oak Grove Dr., Pasadena, Calif. 91109; 818-354-4321.

Power Engineering Society Winter Meeting (PE); Jan. 31–Feb. 5; Hyatt Regency Hotel, Columbus, Ohio; T.C. Wong, American Electric Power Service Co., One Riverside Plaza, Columbus, Ohio 43215; 614-223-2235; fax, 614-223-2205.

FEBRUARY

Ninth Semiconductor Thermal Measurement and Management Symposium—Semi-Therm (CHMT); Feb. 2–4; Four Seasons Hotel, Austin, Texas; Alfonso Ortega, University of Arizona, Department of Aerospace and Mechanical Engineering, Tucson, Ariz. 85721; 602-621-6787; fax, 602-621-8191.

Workshop on VLSI (C); Feb. 7–10; Asilomar Conference Center, Monterey, Calif.; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Wattec '93 (Oak Ridge Chapter); Feb. 16–19; Hyatt Regency Hotel, Knoxville, Tenn.; John W. Shipp Jr., Tennessee Valley Authority, 601 W. Summitt Hill, OCH 1E, Knoxville, Tenn. 37902; 615-632-6426.

Optical Fiber Communication/International Conference on Integrated Optics and Optical Fiber Communication (COM, LEO); Feb. 21–26; San Jose Convention Center, San Jose, Calif.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331.

European Conference on Design Automation with the European Event on ASICs (C, CAS); Feb. 22–25; CNIT–La Défense, Paris, France; Bernard Courtois, TIM3 Laboratory, 46 Ave. Felix Viallet, 38031 Grenoble Cedex, France; (33+76) 57 4615; fax, (33+76) 47 3814.

IEEE members attend more than 5000 IEEE professional meetings, conferences, and conventions held throughout the world each year. For more information on any meeting in this guide, write or call the listed meeting contact. Information is also available from: Conference Services Department, IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855; 908-562-3878; submit conferences for listing to: Ramona Foster, *IEEE Spectrum*, 345 E. 47th St., New York, N.Y. 10017; 212-705-7305.

For additional information on hotels, conference centers, and travel services, see the Reader Service Card.

Books

(Continued from p. 8)

Judiciary and in the final chapters of Bruce Smith's recent book, *The Advisers: Scientists in the Policy Process.*

During the period covered by this history, some very successful science advisory structures grew up in executive branch agencies and in Congress. These include the Environmental Protection Agency's Science Advisory Board, the Defense Department's Defense Science Board, and, in Congress, the Office of Technology Assessment and the Congressional Research Service. Although in the United States (and elsewhere, for that matter) people tend to be preoccupied with the President and the White House, most of the real work of government gets done in other places. Thus it is appropriate to ask about the relative impacts of these systems and how, if at all, they have interacted with the activity of advising the President.

Unfortunately, the author provides no such discussion, and this omission is only partly explainable by the book's focus on nuclear arms. Both the Defense Science Board and the Office of Technology Assessment have played key roles in defense policy debates in which the presidential science advisory apparatus was also a central player.

Without question, physicists have dominated the last half century of presidential science advising. Even so, Herken overplays their dominance. For example, the early chapters on the second World War devote extended discussion to Leo Szilard and several other nuclear physicists while giving only glancing attention to Bush, an electrical engineer who served throughout the war as President Roosevelt's key adviser on a wide variety of scientific and technical matters.

Despite such limitations, *Cardinal Choices* is a valuable addition to the growing literature on the history of U.S. science and technology policy. It deserves a wide readership. Once those new to this field have read this book, they will find Herken's nine-page bibliography to be one of the best reading lists available for further exploration of this fascinating and important topic.

M. Granger Morgan (F) is head of the Department of Engineering and Public Policy at Carnegie Mellon University in Pittsburgh, where he is also a professor in the Department of Electrical and Computer Engineering. His research deals principally with problems in technology and public policy. He is a member of IEEE Spectrum's *editorial board.*

COORDINATOR: Glenn Zorpette

Recent books

Technically Speaking. *D'Arcy, Jan*, Amacom Books, New York, 1992, 224 pp., $28.95.

Fuzzy Systems Theory and Its Applications. *Terano, Toshiro, et al.*, Academic Press, New York, 1992, 268 pp., $49.95.

Database Design. *Rishe, Naphtali*, McGraw-Hill, New York, 1992, 510 pp., $44.95.

ISDN and Broadband ISDN, 2nd edition. *Stallings, William*, Macmillan, New York, 1992, 633 pp., $53.

Television Engineering Handbook, Revised. *Benson, K. Blair,* and *Whitaker, Jerry*, McGraw-Hill, New York, 1992, 350 pp., $99.95.

Difference Equations and Inequalities Theory, Methods, and Applications. *Agarwal, Ravi P.*, Marcel Dekker, New York, 1992, 777 pp., $150.

SAA/LU6.2 Distributed Networks and Applications. *Edmunds, John J.*, and *Ranade, Jay*, McGraw-Hill, New York, 1992, 504 pp., $49.95.

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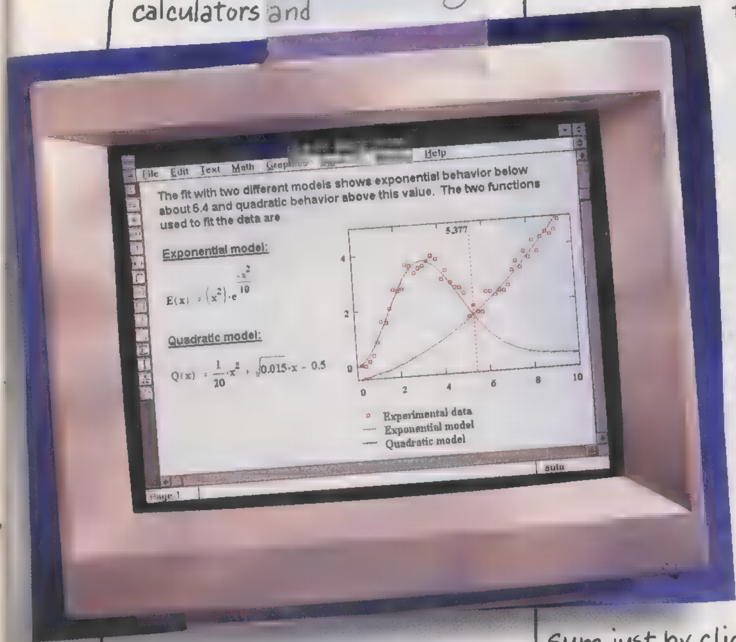

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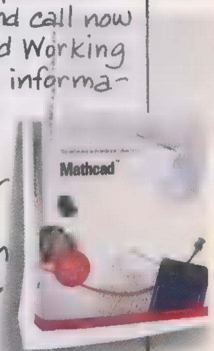

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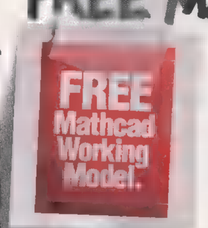

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NUMBER 149

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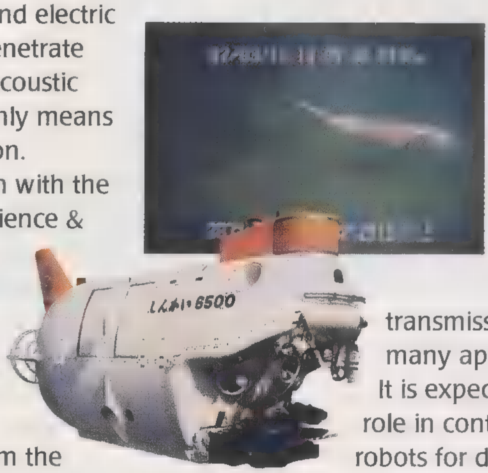

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Since 1977, NEC has used the slogan "C&C" to express our philosophy of technical innovation through the merging of computers and communications.

Our new corporate slogan is "C&C for Human Potential".
The change reflects our expanded vision of C&C as a concept that can deepen mutual understanding, fulfill human potential and contribute to social progress worldwide.

NEC

Reflections

The culture must change

Around the long table heads nodded in unison. Yes, we agreed, the culture must change. Professors should be rewarded according to their teaching effectiveness, not for their fame in research. In sympathetic vibration my own head bobbed up and down, just like the other wise heads.

The nodding continued. I glanced furtively at my neighbor and caught him in the act of monitoring my own degree of sincerity. Not so much as a ripple or a shadow in his expression betrayed any lack of conviction. This was serious stuff; I wasn't going to be the first to stop nodding. I clenched my jaw muscles. People should learn. They shouldn't be so swayed by reputations and publications—teaching should count more than research. The culture should change. Why couldn't everyone be so enlightened and so willing to accept the new order as my esteemed colleagues around this prestigious table?

But in my mind I drifted above the table, looking down on myself. Who was this simpleton below nodding his empty head at the presumed intransigence of other people? Mr. Researcher, no less. This is the person who is going to reward other people for teaching, rather than research?

And look at his associates—a dusty old group of engineers who have made their fame and fortune in research, now decrying the very culture that maintains that research is of paramount importance. Sure. A young person would be really wise to base his career decision to forgo research on the promise of those nodding heads.

Back at old Techless Tech, the young faculty gather in the coffee room. With a nervous glance in the general direction of the heavenward upper floors, one very junior assistant says tentatively, "He says that research doesn't count anymore—that we're going to be promoted solely based upon our teaching abilities."

A somewhat older staff member scoffs. "Ha! Just give up your NSF grant and stop publishing for a semester, and see what happens."

Actually, there seems to be a slight question at the end of this less than confident statement. The older person is currently up for tenure. He is a terrible teacher, and everyone knows it.

A thin woman looks up through the vapor rising from her coffee cup. "He doesn't control the tenure process, anyway," she says flatly. "The committee decides tenure, and take a look at their publication lists if you think you don't have to be writing continuously. They all modeled themselves after *him* in the first place." Sarcasm drips from her words.

Now the older assistant prof—the one up for tenure—breaks the embarrassed silence in the small group. "He doesn't know who is a good teacher and who isn't," he states hopefully. "He can't measure things like that. He'll have to count papers. That's all he can do."

The other people avert their eyes scornfully. *Everybody* knows how bad a teacher this guy is. The young person can't resist putting the needle in, even if it is inevitable that this jerk is going to get the precious tenure slot. "Of course, there are the student surveys . . . ." He lets the thought hang in the air.

"Students!" cries the tenure-seeker. "We're going to let our destinies be decided by a bunch of unwashed students?" A look of sheer terror belies the attempt to feign righteous indignation.

The junior faculty in the lounge crystallizes the dilemma. Who creates and controls the culture in the first place? It is not as if there were an official book somewhere—a loose-leaf binder, of course—entitled *Culture Code*, which would be full of important-sounding stuff like, "Whereas . . ., therefore . . ., behavior will be as follows . . ." (Naturally, it would be written by lawyers.)

My own theory is that the culture is a metaphysical phenomenon. (Really a helpful theory, isn't it?) You could fire all the present professors (after, of course, detenuring them), and replace them all with professional teachers who had never published anything or had a single contract or grant. Sooner or later NSF or some other agency would foist off a grant on one of them, and someone else would bow to the urging of a journal editor to contribute some little piece.

At review time the good teachers would sit around a table, trying to judge the performance of their peers. "You know, old Tom did publish a paper in that journal—whatever it was," someone would say. Someone else would nod in admiration, and in the end Tom would get a bigger raise or a promotion or something. People on campus would start looking up to Tom, and visitors to the school would ask, "Is this the place where the famous Tom teaches?" Inevitably, the resilient culture would revert to its base state.

I don't know where the culture comes from. Every school, every company or institution has its own unique variation. You could get rid of all the people, get new ones, and the culture would still be the same. MIT would still be MIT, Purdue still Purdue, Cal Poly still Cal Poly, and so on. Maybe it hangs in the walls, absorbed in the bricks and mortar, or maybe it is in the names. The students know, and they come already primed with the requisite culture.

Of course, I am just using teaching versus research as an example of people crying out for culture change. I hear it all the time. We should reward engineers who work in factories more than those in development. It should be OK to fail on some project in this company. The Federal labs have to change their culture away from weapons design to commercial applications. Et cetera, et cetera. The culture must change. Whatever the culture is right now, wherever you are, it isn't right. The higher-ups have announced that it should change.

You be the first to change. I'm a little skeptical myself.

Robert W. Lucky

Graphics

A romance with many dimensions

What would a universe look like where, besides the usual up-down, left-right, and front-back, there was another choice—another axis? How about two more axes? Three? Unfortunately, such questions have proved themselves among the most elusive of mysteries, since imagining space with even one more dimension than the usual three seems to lie beyond the natural reach of human intuition.

Nonetheless, for many years, mathematicians have managed to deduce various characteristics of objects in four-dimensional space, and even show what some of them might look like when projected into spaces of a mere two or three dimensions. Much of this work is analogous to the routine projection of the 3-D world into 2-D photographs and paintings.

A relatively short-lived project using computer graphics to show aspects of 4-D space was undertaken by A. Michael Noll at Bell Laboratories in the mid-1960s. But the work can be said to have begun in earnest 25 years ago when Thomas Banchoff, a new member of the mathematics faculty at Brown University in Providence, R.I., began using software written by Charles Strauss, a computer science colleague at Brown, to produce projections of objects rotating in 4-D space. With their limited computational power, however, those early computers could display only the simplest of 4-D shapes and were incapable of interactive visualization in three—let alone four—dimensions.

Now, however, a confluence of powerful workstations, systems for viewing 3-D images on workstation screens, and new software techniques are giving researchers their best views ever of this strange realm. "New machines almost invariably teach us something new" about the fourth dimension, Banchoff said in an interview. Banchoff, still at Brown, expects to teach his course next year in a laboratory equipped with 50 Sun Sparcstation 10, model 41 workstations, many outfitted with graphics accelerator boards.

Banchoff uses such computing power to

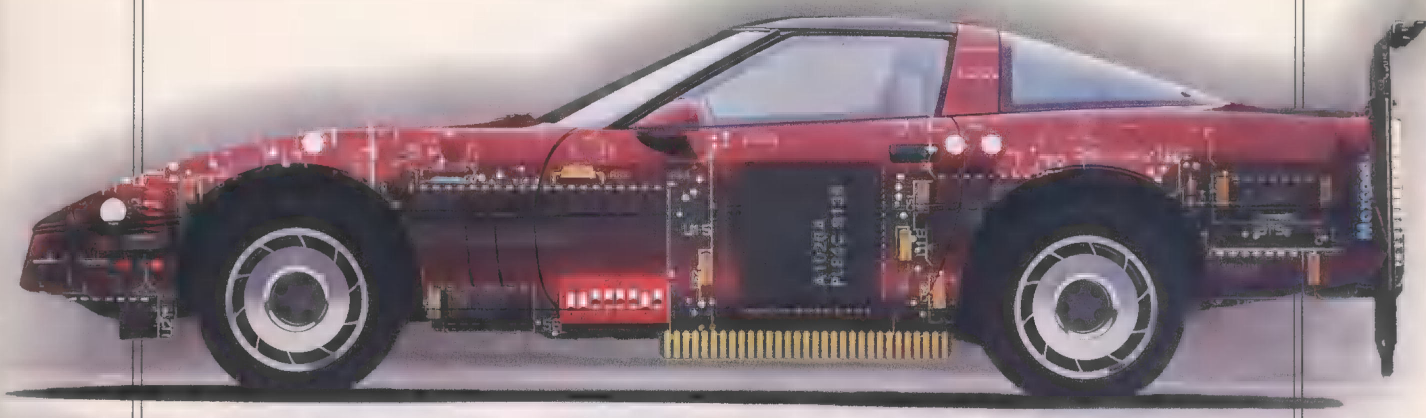
David Kaplan, Thomas Banchoff

Thomas Banchoff, Charles Strauss

Advances in computer graphics are evident in these renditions of Klein bottles made at Brown University in Providence, R.I. The white one was done two decades ago; the colored one is just a few months old.

project and "slice" 4-D objects in different ways, so as to expose their singularities. These are points of sharp discontinuity—cusps, folds, and pleats are all examples of singularities in two dimensions. Much of

(Continued on p. 86)



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Calendar

(Continued from p. 11)

International Solid-State Circuits Conference (SSC et al.); Feb. 24–26; San Francisco Marriott Hotel, San Francisco; Diane S. Suiters, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4255; fax, 202-347-6109.

Second Annual Conference on Evolutionary Programming (NN); Feb. 25–26; Radisson Hotel, La Jolla, Calif.; David B. Fogel, 9363 Towne Centre Dr., San Diego, Calif. 92121; 619-455-5530, ext. 424; fax, 619-453-9274.

MARCH

Third Great Lakes Symposium on VLSI (C, CAS); March 5–6; Western Michigan University, Kalamazoo; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Applied Power Electronics Conference and Exposition—APEC '93 (IA, PEL); March 6–12; Town and Country Hotel, San Diego, Calif.; Virginia Insley, Courtesy Associates, 655 15th St., N.W., Suite 300, Washington, D.C. 20005; 202-639-4990.

10th International Zurich Symposium and Technical Exhibition on Electromagnetic Compatibility (EMC); March 9–11; Swiss Federal Institute of Technology, Zurich; Gabriel Meyer, Symposium Chairman, ETH Zentrum-IKT, CH-8092 Zurich, Switzerland; (41+1) 256 2790; fax, (41+1) 262 0943.

Multichip Module Conference (ED); March 15–18; Cocoanut Grove, Santa Cruz, Calif.; S. Simon Wong, CIS-202, Stanford University, Stanford, Calif. 94305-4070; 415-725-3706; fax, 415-725-6949.

19th Annual Northeast Bioengineering Conference (EMB); March 18–19; New Jersey Institute of Technology, Newark; Stanley Reisman, ECE Department, New Jersey Institute of Technology, Newark, N.J. 07102; 201-596-3527.

International Conference on Microelectronic Test Structures (ED); March 22–25; Gran Sitges Hotel, Barcelona, Spain; Loren W. Linholm, National Institute of Standards and Technology, B360 Technology Building, Gaithersburg, Md. 20899; 301-975-2052; fax, 301-948-4081.

International Reliability Physics Symposium (ED); March 22–25; Hyatt Regency Hotel, Atlanta, Ga.; David A. Baglee, 5604 Cometa Court N.E., Albuquerque, N.M. 87111; 505-893-3446.

Topical Symposium on Combined Optical-Microwave Earth and Atmosphere Sensing (LEO); March 22–25; Hyatt Regency Hotel, Albuquerque, N.M.; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3894.

Second International Workshop on Software Reusability—IWSR-2 (C); March 24–26; Villa Bottini, Lucca, Italy; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

European Workshop on Refractory Metals and Silicides (ED); March 28–31; De Ruwenberg, St. Michielsgestel, the Netherlands; D. Van De Laak or G. Janssen, DIMES/Delft University of Technology, Box 5046, 2600 GA Delft, The Netherlands; (31+15) 782 600 or 786 063.

International Conference on Neural Networks—ICNN '93 (NN); March 28–

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Calendar

April 1; San Francisco Hilton, San Francisco; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222; fax, 619-535-3880.

Second International Fuzzy Systems Conference (NN); March 28–April 1; San Francisco Hilton, San Francisco; Nomi Feldman, Meeting Management, 5665 Oberlin Dr., Suite 110, San Diego, Calif. 92121; 619-453-6222.

Electronics and Instrumentation Conference and Exhibit (Cincinnati Sections); March 30–31; Albert B. Sabin Cincinnati Convention Center, Ohio; Kevin Sullivan, Box 15044, Cincinnati, Ohio 45215; 513-397-6256.

International Symposium on Autonomous Decentralized System (C); March 30–April 1; Hitachi System Plaza, Kawasaki, Japan; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

APRIL

Southeastcon '93 (Region 3, Charlotte Section); April 4–7; Hilton of University Place, Charlotte, N.C.; Silvia G. Middleton, Box 520, Newell, N.C. 29126; 704-547-2301.

IEEE/ASME Joint Railroad Conference (VT); April 6–8; Vista International Hotel, Pittsburgh; Joseph U. Castellani, AEG Westinghouse Transportation Systems Inc., 1501 Lebanon Church Rd., Pittsburgh, Pa. 15236; 412-655-5270.

International Conference on the Numerical Analysis of Semiconductor Devices and Integrated Circuits—Nasecode (ED); April 13–16; Copper Mountain Resort, Copper Mountain, Colo.; John J.H. Miller, University of Dublin, 39 Trinity College, Dublin 2, Ireland; (353+1) 679 7655; fax, (353+1) 679 2469.

First International Workshop on Systems Management (C); April 14–16; Faculty Center, University of California, Los Angeles; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Workshop on Research Issues in Data Engineering: Interoperability in Multi-Database Systems (C); April 18–20; Penta Hotel, Vienna, Austria; IEEE Computer Society, Conference Department, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

International Conference on Indium Phosphide and Related Materials (ED); April 18–22; Maison de la Chimie, Paris, France; Susan Evans, IEEE/LEOS, 445 Hoes Lane, Piscataway, N.J. 08855-1331; 908-562-3896; fax, 908-562-1571.

Second Annual Symposium on Document Analysis and Information Retrieval (C); April 26–28; Caesars Palace Hotel, Las Vegas; W. L. Brogan, University of Nevada, 4505 Maryland Parkway, Las Vegas, Nev. 89154-4026; 702-597-4183.

International Conference on Acoustics, Speech and Signal Processing (SP); April 27–30; Minneapolis Convention Center, Minnesota; Mostafa Kaveh, Department of Electrical Engineering, University of Minnesota, 200 Union St., S.E., Minneapolis, Minn. 55455; 612-625-0720.

MAY

Power Industry Computer Applica-

Calendar

tions Conference (PE); May 4–7; Registry Resort and Scottsdale Plaza Resort, Scottsdale, Ariz.; Matt Tani, Arizona Public Service Co., Box 53999, Mail Station 2387, Phoenix, Ariz. 85072-3999; 602-250-1055; fax, 602-250-1050.

Custom Integrated Circuits Conference (ED); May 9–12; Town and Country Hotel, San Diego, Calif.; Roberta Kaspar, 1597 Ridge Rd. West, Suite 101C, Rochester, N.Y. 14615; 716-865-7164.

Photovoltaic Specialists Conference (ED); May 10–14; Galt House, Louisville, Ky.; E. Boes, National Renewable Energy Laboratory, Suite 710, 409 12th St., S.W., Washington, D.C. 20024; 202-484-1090.

15th Annual Electronics Exposition and Symposium (Albuquerque Section); May 11–13; Albuquerque Convention Center, New Mexico; Meridee Katz, 8100 Mountain Rd., N.E., Suite 109, Albuquerque, N.M. 87110-7827; 505-262-1023.

International Symposium on VLSI Technology Systems and Applications (ED); May 12–14; Lai Lai Sheraton, Taipei, Taiwan; G. J. Hu, Cypress Semiconductor, MS/1-1, 3901 N. 1st St., San Jose, Calif. 95134; 408-943-4861; fax, 408-943-2118.

International Workshop on VLSI Process and Device Modeling—VPAD (ED); May 14–15; New Public Hall, Nara, Japan; Masao Fukuma, Microelectronics Research Laboratories, NEC Corp., 1120 Shimokuzawa, Sagamihara, Kanagawa 229, Japan; (81+42) 771 0798.

International Symposium on Power Semiconductor Devices and ICs (ED); May 17–19; Hyatt Regency Monterey Hotel, Monterey, Calif.; M. Ayman Shibib, AT&T Bell Laboratories, Box 13566, Reading, Pa. 19612-3566; 215-939-6576.

VLSI Technology Symposium (ED); May 17–19; Kyoto Grand Hotel, Kyoto, Japan; James T. Clemens, AT&T Bell Laboratories, 600 Mountain Ave., Murray Hill, N.J. 07974; 908-582-2800; fax, 908-582-2793.

Instrumentation and Measurement Technology Conference (IM); May 18–20; Hyatt Regency Hotel, Irvine, Calif.; Robert Myers, 3685 Motor Ave., Suite 240, Los Angeles, Calif. 90034; 310-287-1463.

University/Government/Industry Microelectronics Symposium (ED); May 18–20; North Carolina State University, Raleigh; Jeffrey A. Coriale, North Carolina State University, Box 7920, Centennial Campus, Raleigh, N.C. 27695; 919-515-5053; fax, 919-515-5055.

35th Cement Industry Technical Conference (IA); May 23–27; Royal York Hotel, Toronto; John MacRitchie, Leeds & Northrup Canada, 1344 Fewster Dr., Mississauga, Ont., Canada L4W 1A4; 416-238-6850.

23rd International Symposium on Multiple Valued Logic (C); May 24–27; Hyatt Regency Hotel, Sacramento, Calif.; K.W. Current, ECE Department, University of California, Davis, Calif. 95616; 916-752-0583; fax, 916-752-8428.

Canadian Workshop on Information Theory (IT, Region 7); May 30–June 2; Le Riviera Conference Centre, Rockland, Ont.; T. Aaron Gulliver, Department of Systems and Computer Engineering, Carleton University, Ottawa, Ont., Canada K1S 5B6; 613-788-5734; fax, 613-788-5727.

JUNE

International Symposium on Electron,

(Continued on p. 86C)

Program notes

The benign attack of the BLOb

Most of today's popular relational database structures were developed expressly to store numerous small blocks of characters; they cannot store large, unformatted blocks of data. Enter multimedia, which requires the use, and storage, of sound, graphics, and video images—that is, large, unformatted blocks of data.

One technique programmers can use to extend traditional database structures is to add BLObs (Binary Large Objects) to them. Like other data elements, BLObs are associated with fields in database records, so that, like other fields, they are under full transaction control and concurrency. Usually, only a portion of each BLOb (usually a handle that identifies the location of the BLOb and a short leader that describes its contents) is stored in the base table of the database. The BLOb itself is stored with other BLObs in a container file linked to the base table.

In addition to BLObs, BLOb filters may be stored in the enhanced database. These filters are methods for manipulating other BLObs. A BLOb filter for an image BLOb, for example, might well contain code for displaying a graphic BLOb on certain graphics systems, printing the image on certain printers, and translating the image to other graphics formats. A BLOb filter for a test data BLOb would typically contain a description of the test instrument, the test conditions, and code for displaying the data in tabular and graphical formats.

The database team of Borland International Inc., Scotts Valley, Calif., decided to add BLOb data types and filters to all new database products. The database structure for both Paradox 4.0 and Borland's new Windows database product, Paradox for Windows, allows BLObs. Also, Borland has added BLObs to the latest release of the Paradox Engine, the company's C and Pascal toolbox for creating and manipulating Paradox databases.

More information on BLObs is available. *Contact: Borland International Inc., Interbase Div., 1800 Green Hills Rd., Box 660001, Scotts Valley, Calif. 95067-0001; 800-245-7367 or* **circle 110**.

Easing into C++

Migrating from C to C++ can be a daunting task for anyone who has many lines of code that need converting. Days or even weeks may be needed for more complex problems—say, finding and modifying all C functions that use the empty function call (foo()) but do not mean that the function takes no arguments (foo(void)) as in C++. In such cases, which are not uncommon, it has been easier to rewrite all the source code from scratch in C++ than to fix all the C/C++ incompatibilities.

With its High C/C++ compiler, MetaWare Inc., Santa Cruz, Calif., offers an alternative migration path, which it calls incremental strengths. With incremental strengths, the programmer has the ability to tune the compiler to any of four levels of C++ compatibility.

At the extreme levels (levels 0 and 3) are

(Continued on p. 83)

Legal aspects

Software copyrights: searching for the golden nugget

Joel Miller

Your competitor has just released a new engineering software package. From a cursory examination, you conclude that it's virtually identical to one of your own products. Indeed, it has all the same features. Worse yet, one of your former senior software engineers is the apparent brains behind this new package. If you don't do something quickly, the US $5 million you invested in the product will be lost. But what can be done? Is your competitor's product truly an infringement of yours?

A similar question was addressed in *Computer Associates International, Inc. v. Altai, Inc.*, decided last June by the U.S. Court of Appeals for the Second Circuit in New York City. The appeals court upheld the trial court's ruling that the nonliteral aspects of a software program—features not embodied literally in the software code—had not been infringed.

The software in question was an interface module, a program that permits one to use specific application packages on more than one type of computer without having to develop and maintain a separate package for each operating system. Instead, the interface bridges the differences between a specific operating system and the application. Computer Associates International (CA), Garden City, N. Y., had developed an interface called Adapter and used it with CA's various software packages, including one called Scheduler, a job-scheduling program for IBM mainframe computers.

Altai, Arlington, Texas, a competitor of CA, had its own job-scheduling program and, hoping to achieve the same advantage as CA, set out to create its own interface program, which it labeled Oscar 3.4. Unbeknownst to Altai's management, one of its designers had formerly worked on the Adapter software module at CA and had taken a copy of the program with him when he left. Armed with that software, he created Oscar 3.4.

Suspecting that portions of Adapter had been misappropriated, CA brought suit against Altai. As it turned out, 30 percent of Oscar 3.4 came straight out of CA's Adapter.

Only after the lawsuit started did Altai learn about its errant employee and Adapter. Altai then rewrote the package, stripping out anything related to Adapter, and produced Oscar 3.5, the subject of the appellate court's decision.

But even with the rewrite, CA contended that Oscar 3.5 infringed the copyright for Adapter, claiming that the new module still retained the same structure, as well as similar parameter lists and macros.

GETTING IN THE DOOR. Before reaching the issue of whether Oscar infringed CA's rights in Adapter, the court had to determine whether CA owned a valid copyright.

To bring suit for copyright infringement in the United States, you must have a copyright registration for your program. You obtain a registration by filing an application in the Copyright Office, together with a deposit of the program and a $20 application fee.

The deposit requirement is usually met by submitting a copy of the source code. But bear in mind that copyright applications and their accompanying deposits are open to public inspection. If there are trade secrets in the source code that you would prefer not to disclose, the Copyright Office will permit you to use an alternative method for deposit. For example, you may submit the first 25 and last 25 pages of the source code, to avoid disclosing trade secrets that reside elsewhere in the code, or you may provide the object code in lieu of the source code. Since the contents of the deposit could have other ramifications, you should carefully research this issue or consult an expert in this area.

Although you could wait until just before you go to court to submit a copyright application, you could lose some fairly significant advantages you would have acquired had you applied before or at the time you first "published," that is, distributed, the program. For example, two benefits of a timely registration are statutory damages and attorneys' fees, which figured heavily in the recovery awarded in the *Basic v. Kinko's* photocopying case discussed in an earlier column [*IEEE Spectrum*, July 1992, p. 20]. If you fail to register a work within the proper timeframe, you will not be entitled to these damages and fees, and may end up with only a paper victory.

NO SMOKING GUN. Having established that you have a registration and are entitled to proceed with the case, you must prove that copying occurred. If you do not have direct evidence of copying—an admission, for example—you can satisfy this element by showing that the infringer had access to the program and that the accused item is substantially similar to the protected work. In the *Altai* case, the court handily disposed of the access issue since Altai's employee had admitted taking a copy of Adapter.

Up to this point, the *Altai* decision is

(Continued on p. 84)

Mathematica

THE DEFINITIVE SYSTEM FOR TECHNICAL COMPUTATION

"Not merely a product but a revolution"
— *Macworld*

"The importance of the program cannot be overlooked"
— *New York Times*

Basic function: Integrated environment for numerical, symbolic, graphical computation, interactive programming.

Users: Scientists, engineers, mathematicians, programmers, financial analysts, students. Over 150,000 worldwide. Includes all 50 largest U.S. universities.

Numerical computation: Arbitrary-precision arithmetic, complex numbers, special functions (hypergeometric, elliptic, etc.), combinatorial and integer functions. Matrix operations, root finding, function fitting, Fourier transforms, numerical integration, numerical solution of differential equations, function minimization, linear programming.

```
Numerical Computation
In[1]:=
  3^70
Out[1]=
  2503155504993241601315571986085849
In[2]:=
  Hypergeometric2F1[7, 5, 4.1, 3-I]
Out[2]=
  -0.00403761 - 0.00295663 I
```

Symbolic computation: Equation solving, symbolic integration, differentiation, power series, limits. Algebraic operations, polynomial expansion, factorization, simplification. Operations on matrices, tensors, lists, strings.

```
Symbolic Computation
In[1]:=
  Integrate[x / (a + Exp[x]), x]
Out[1]=
   2             x                      x
  x    x Log[1 + E ]   PolyLog[2, -(E )]
                 --                  --
                 a                   a
  -- - ------------- - -----------------
  2 a        a                a
```

Graphics and sound: 2D, 3D plots of functions, data, geometrical objects. Contour, density plots. 3D rendering with intersecting surfaces, lighting models, symbolic descriptions. Color PostScript output, combining and labeling, publication quality graphics, animation (most versions). Sound from waveforms and data (most versions).

Programming: High-level, interactive, symbolic language. Procedural and functional programming constructs. Transformation rules and pattern matching. Fully compatible on all platforms. No built-in limitations on computation size.


Graphic generated and rendered with Mathematica.

```
Programming
log[1] = 0
log[E] = 1
log[x_ y_] := log[x] + log[y]
log[x_ ^n_] := ■ log[x]
log'[x_] = 1/x (* derivative *)
log/: InverseFunction[log] = exp
log/: Series[log[x_], {x_, 1, n_}] :=
      Sum[-(-1)^k (x-1)^k/k, {k, 1, n}] +
       O[x, 1]^(n+1)
```

External interface: Input of data (numbers, records, text) from files, programs. Output in TeX, C, Fortran, PostScript. Calling of external programs and functions. General *MathLink*® interprocess communication mechanism.

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Circle No. 14

JANUARY 1993 Volume 30 Number 1

Conversion initiatives

Several years ago, during a modest recession, IEEE initiatives included a foray into the realm of technological forecasting. Such an exercise would help define the potential areas of development and link them more realistically to promising concepts for products, services, and applications. It would also help engineers whose jobs were threatened to prepare themselves for a transition to more viable employment. Or so the reasoning went.

Afterwards, it was hard to measure the success of the forecasting effort. There was, however, a noticeable tendency among prospective users of the forecasts to discount any that extended beyond a year or so. Forecasting experts say this phenomenon is a hazard encountered by all forecasters, one abetted by the fact that most longer-term forecasts are not accurate.

The IEEE is now taking a different tack, and last April began a project to create a "portfolio" of emerging technologies. The effort is being led by the IEEE Societies and the resulting document is intended to be updated annually. The New Technology Directions Committee, under whose auspices the project is going forward, expects to identify emerging trends that could be crucial for long-range career planning and a stimulus to the creation of new technical enterprises. On p. 81 of this issue, some of the technologies thus far identified are discussed.

In still another initiative, a group of concerned U.S. members, responding to President-Elect Clinton's transition team's request to IEEE-USA for advice, provided a confidential list of "ideas for change." Some of these ideas concern the elements of a national policy for converting defense spending to civilian needs, science education policies, the role of the Department of Commerce in civilian technology, reform of data rights to encourage commercialization, competition in multichannel television, the private sector in space, and creating a biomedical engineering entity at the National Institutes of Health.

* * *

At the end of World War II there was a pent-up demand for consumer goods in the United States and other (both Allied and Axis) countries. Today, with the cessation of the Cold War, no such demand exists in the United States, but it does in the former Eastern Bloc countries. Thus many U.S. companies, as well as multinationals, see the Eastern Bloc as a huge potential market. Indeed, some companies view investment in these markets, and, indeed, helping these countries establish a manufacturing base, as prime strategies to bolster their own standing.

Strategies for the development of markets within the United States are quite another matter. Some economists think a concerted attack on environmental and energy problems would be a win/win situation. But they note that high costs, at least initially, would require government intervention. For example, there would have been little hope for a viable market in electric vehicles without the legislation enacted in California, New York, and Massachusetts, requiring minimum quotas to be sold by the auto makers. Now, spurred by the legislation, General Motors Co. hopes for commercial production of the Impact, its nominee, in the mid '90s, and Ford, Chrysler, Fiat, and Volkswagen have small production quantities of electric vehicles planned or under way.

The Clinton administration has suggested a renewed emphasis on alternate-energy development and on energy-efficient products and applications. Appropriate legislation could help drive these efforts, as, for example, in taxing or barring energy-inefficient devices.

The Federal government itself could require more economical use of energy in its own buildings and appliances, thus providing a model for others to follow and helping enlarge the market for advanced techniques. There's also some indication that the Department of Energy (DOE) will be encouraged to shift emphasis in its research programs to conservation technologies and renewable resources, as opposed to programs in nuclear energy and coal.

The DOE might also be directed to make its technology for the cleanup of nuclear weapons plants generally available to private industry.

* * *

Conversion initiatives notwithstanding, the economy may respond reluctantly.

Charles M. Armstrong, chairman and chief executive officer of Hughes Aircraft Co., in remarks he made to a Wescon audience last November, criticized the plan to shrink the military industry by one-third in just five years. "We surely don't need five years to downsize our defense base, to lay off hundreds of thousands of people, to abandon facilities across the country and to create a substantial socio-economic impact. But we do need more than five years to reapply technology, to create new products and businesses that can employ so many of these talented engineers and workers and contribute to the rebuilding of our country's economic base," Armstrong said. He called for a 10-year plan for successful diversification—a plan that goes beyond "just this election."

And Robert Polutchko, technical and production operations vice president for Martin Marietta Corp., observed that most plans to convert military contractors in part to commercial products do not fully consider all the issues. They often fail to explain how the associated business risks will be mitigated, or where the capital for commercialization will come from, he notes, or how a company with a built-in "defense culture" is supposed, overnight, to change into one with an appropriate "commercial culture."

Adding weight to expectations of a rough road ahead, the executive director of the Industrial Research Institute (IRI) in Washington, D.C., Charles Larson, said that over 85 percent of the 141 firms responding to an IRI survey expected their R&D professional staffing to drop or stay the same in 1993, 28 percent expected to decrease their R&D expenditures, and 36 percent planned to decrease capital spending for R&D.

Thus, it seems that in spite of numerous laudable efforts by individuals, industry, governments, and professional societies, the road to conversion success and a rebounding economy will be long and difficult.

Donald Christiansen

TECHNOLOGY 1993

- **PCs and workstations**
- **Software**
- **Large computers**
- **Telecommunications**
- **Data communications**
- **Solid state**
- **Test and measurement**
- **Industrial electronics**
- **Power and energy**
- **Consumer electronics**
- **Transportation**
- **Aerospace and military**
- **Medical electronics**

Every January, the editors of *IEEE Spectrum* and invited experts review many products and assess trends in technology. This past year's highlights? The downsizing of supercomputers, the movement of cable television firms and local telephone companies into each other's industries, and the dampening effect the recession and the Cold War's end had on military and aerospace activities.

Though confining our emphasis to the past year (1992), we also look ahead to product developments and industry trials anticipated over the next six months (1993). Things to watch for this year include the first trials of wireless personal communications services, the greater use in medical electronics of lasers in sculpting nearsighted eyes, and the commercialization of high-speed digital networks.

Laws, regulations, and standards also influenced the scene. Whether or not certain communications services have a chance at commercial existence was determined in part last February at the 1992 World Administrative Radio Conference.

Here, in more detail, are some of the highlights in each of the major fields we cover.

In personal computers, the subnotebook variety, which weigh less than a kilogram, spurred several developments in peripherals, notably a credit-card–sized hard disk drive. But most observers agree that pen-based computers may take longer than at first expected to become useful products.

Meanwhile, some of the key software companies have been weakened by a lackluster global economy. The industry has also seen an extraordinary shift from minicomputers and mainframes to PCs and workstations, as well as an expansion of outsourcing software groups. The developers of operating systems competed fiercely, with no clear winner among Windows, OS/2, and all the Unix siblings.

Trudy E. Bell Issue Editor

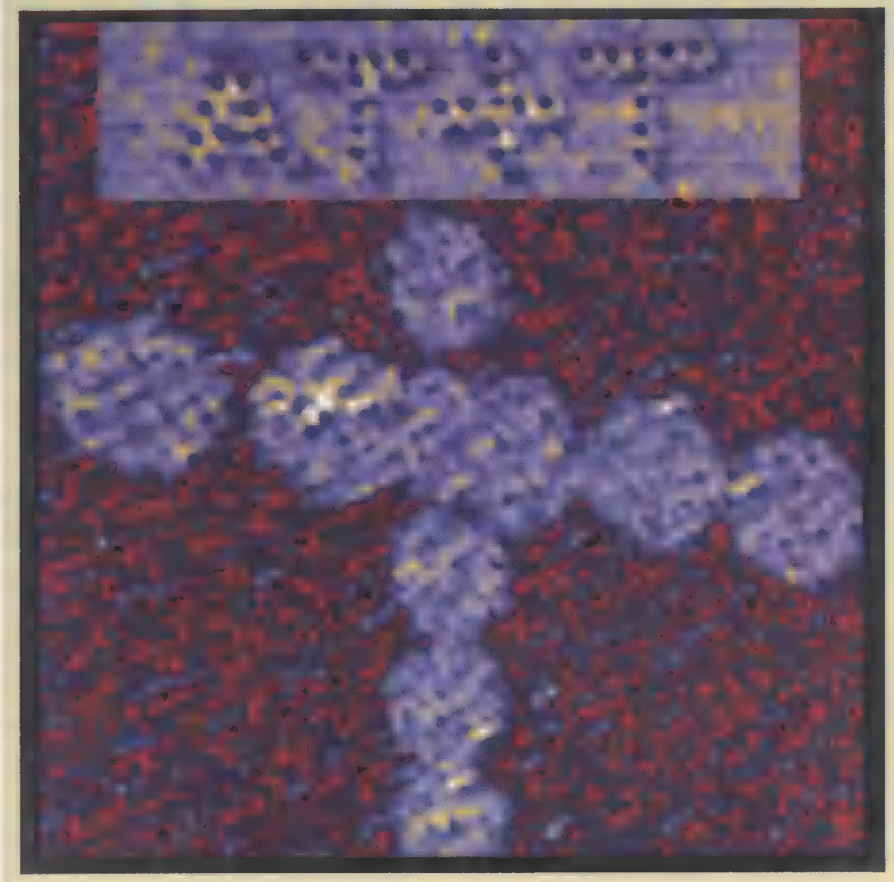
The market in large computers has been disrupted not only by technological progress, but also by the recent recession coupled with the move toward so-called open systems based on industry-standard operating systems and a greater interest in parallel processing. The result: downsizing. Mainframes are giving way to networks of personal computers served by a mid-range computer, while workstation clusters are substituting for supercomputers.

In telecommunications, 1992 may be remembered as the year when desktop and portable computers, telephones, facsimile machines, cable television, CD ROM, audio receivers, and other devices in the office and home could all be connected globally—both through wires and radio links—not just through prototypes and technology trials, but in commercial systems. And a dark horse is shaping up as a player in the provision of merged phone, data, and multimedia services: cable television.

Last year data communications made strides toward high-speed data highways with the establishment of the ATM Forum (an association of more than 150 worldwide organizations involved in asynchronous transfer mode switching), and progress continued toward the U.S. government's gigabit-per-second National Research and Education Network (NREN). In addition, alternative means of transmitting high-speed data included the proposed use of low–earth-orbiting satellites. On the down side, activity on the integrated services digital network (ISDN) was slower than expected in the United States for most of the year.

In solid state, one of the biggest technology drivers last year was a demand for new devices in notebook/palmtop computers. The need of those devices for high integration and low power has accelerated the production of 3.3-V products by almost every manufacturer of digital semiconductors. Multimedia is one of the fastest-growing

THE MAIN EVENT



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mixed-signal applications, and it went consumer this year with the introduction of low-cost, dedicated ICs. And Digital Equipment Corp.'s new Alpha chip, operating at 150 MHz, is to find its way into supercomputers.

In test and measurement, software-controlled instrumentation has taken hold, with the VXIbus becoming one of the main standards. National Instruments Corp.'s LabVIEW, designed for the Apple Macintosh, last year also came out for PC-DOS users as LabVIEW for Windows, giving users of PC- and VXI-based instruments elegant software for setting up and controlling instrument systems.

In spite of a generally stagnant global economy, there were notable advances in industrial electronics. They included improved precision in computer numerical control (CNC) for machine tools; easier, high-level programming for programmable logic controllers; faster and more efficient machine vision; X-ray laminography tailored to surface-mounted boards; and more powerful power electronics devices.

Two of last year's signal developments in power and energy were unconnected policy developments: the passage of comprehensive energy legislation by the U.S. Congress and the Earth Summit meeting on global warming held in Rio de Janeiro last July. Those events, plus other factors, point to the '90s as a time when the emphasis will be on keeping customer loads as low as possible through efficient products.

The birth of new consumer electronic products has been sparked by technical innovations and regulatory actions. In the United States, the Federal Communications Commission—anticipating the selection of a high-definition television (HDTV) transmission standard by year-end—outlined a broad regulatory framework for the U.S. transition to HDTV. Worldwide, broadcasters are preparing for digital audio broadcasting from terrestrial and satellite transmitters, with radio reception approaching the quality of compact audio discs.

Environmental concerns and growing congestion continued to push the transportation industry toward cleaner transit systems moving more passengers, and toward better communications and guidance. In other industry news, the United States is catching up with Europe with new laws requiring access to public places for the handicapped; the electric car market has been rejuvenated; and a magnetic levitation train will be under construction this year in the United States. A submarine with magnetohydrodynamic drive was also tested.

The end of the Cold War and the worldwide recession have forced many of the world's aerospace companies to retrench and have threatened several defense and space projects. The European Space Agency, curtailing its plans for manned space flight, has turned its mini-shuttle Hermes into an unmanned technology development program, and the European Fighter Aircraft, a counter to the Soviet military threat, was itself threatened when Germany canceled its funding after the dissolution of the USSR.

In medical electronics, new implantable defibrillators emerged for people at risk of possibly fatal heart rhythms; ophthalmic lasers were used to correct vision by reshaping the eye; and, at long last, biosensors, devices that marry biological materials with electronics to monitor a body's state, became commercially available. However, unprecedented delays by the U.S. Food and Drug Administration in approving new medical devices angered the $35-billion-a-year U.S. medical electronics industry.

In the specialties, multimedia confronts the need for storage ample enough to handle full-motion television images; magnetic materials and technologies may meet that need with increased storage density and signal-to-noise ratio; and engineering education is going from good to better through interdisciplinary approaches.

Meanwhile, the New Technology Directions Committee of the IEEE's Technical Activities Board (TAB) has begun to produce an annual *Portfolio of Emerging Technologies*, to help the technical societies, the standards community, and individual engineers. ◆

One of the most noteworthy developments in 1992 came out of a laboratory. A lensless technique originating in work to perfect a more powerful optical microscope may well lead to nanometer-scale accuracy in the inspection of optical fibers and integrated circuits, and to storage densities an order of magnitude higher than conventional magneto-optic techniques. Called near-field scanning optical microscopy (NSOM), the lensless technique can write a bit or inspect a surface with a resolution smaller than the wavelength of light being used.

Demonstrated by a research team at AT&T Bell Laboratories in Murray Hill, N.J., the NSOM technique achieves all this by combining three activities: focusing laser light through an optical fiber that tapers to a tip smaller than the light's wavelength; holding the tapered tip closer than the laser wavelength to the surface to be written; and scanning that surface in a raster pattern.

In the usual magneto-optical data-storage systems, a bit is written by focusing light from a semiconductor laser through a lens to heat a spot on the magneto-optic material; microscopes generally use a lens to image a surface lit by white light. The smallest bit that can be written or the closest pair of features that can be resolved is limited by the diffraction of light to about a wavelength.

"What most people don't realize is that the diffraction limit is not fundamental," said the team's leader, Eric Betzig. Instead, it is a mathematical approximation arising from the fact that "the lens or light source is many wavelengths of light away from the surface on which you are writing." But if the light source is held closer to the surface than a wavelength of light and itself is much narrower than the wavelength of light, "you can beat the diffraction limit," Betzig said. He is a member of the technical staff in the semiconductor physics research department.

According to Betzig, the lensless NSOM technique can write a bit smaller than 60 nm or resolve features that are about 12 nm apart. In the AT&T technique, the laser light is directed through a tapered single-mode optical fiber of the type standard in communications systems. The taper is formed by heating the fiber and then stretching it "like taffy" into a thread until it breaks. Even though the glass is amorphous, it spontaneously cleaves along a flat face perpendicular to the pulling axis, forming a tapered fiber with a flat end a mere 20 nm across. The tapering fiber is coated with opaque aluminum, so that light injected into the wide end can emerge only through the narrow flat tip.

Betzig's team borrowed the scanning techniques of the scanning tunneling microscope. The tapered fiber's tip is kept 10 nm from the surface by a shear-force regulator, which measures the drag caused by air between the tip and the sample and adjusts the distance to maintain a constant drag.

When used as a microscope, the tapered-fiber probe detects light, rather than emitting it, and so is useful for monitoring the composition of certain materials. For example, in long-distance optical-fiber communications, the gain in an erbium-doped fiber amplifier is strongly affected by the distribution of the atoms of the rare-earth element erbium in the silica fiber core; ideally, they should be concentrated in the core's center.

The distribution of erbium in the core can be mapped by the NSOM tip used as both light source and probe. Blue laser light at 488 nm shines out of the tip as it scans across the face of the erbium-doped fiber and excites the erbium atoms to fluoresce at the infrared wavelength of 1.5 μm. Since the fiber core has a higher index of refraction than its cladding, it returns more of the light and the core-cladding boundary is distinct; thus, the probe can map the position of the erbium with submicrometer resolution.

Using the tip as a write head for magneto-optic storage on a conventional magneto-optic material, Betzig's team achieved nearly 100 times the density of today's best commercial methods—approaching 7 Gb/cm^2. They have written bits a mere 60 nm across and their centers 120 nm apart. As a stunt, Betzig's team lined up 100-nm bits to form the letters "AT&T," with each letter fitting inside a single bit written by the standard lens technique [see photograph].

AT&T is considering options for commercialization. *—T.E.B.*

PCs and workstations

- **Competition squeezes profits**
- **Workstations do battle over performance**
- **The PC price wars**
- **The fast dwindling disk-drive**

There was money to be made in computers last year. Unhappily, one way was by selling red ink to some of the largest manufacturers so that they could record their losses. The hard times kept many others hard up or worse, despite some bright spots.

Money was not the sole problem, either. Industry leaders were forced to adapt to the focused competition, reduced margins, and slower growth of a maturing computer business. Restructuring and reductions of engineering jobs occurred even at Bull, Compaq, Digital, Fujitsu, Hewlett-Packard, IBM, Olivetti, and Siemens/Nixdorf. Further, lower corporate earnings will probably translate into less money for research and development, pressuring companies to increase R&D productivity.

Clearly, a new business environment is developing for computing companies. Indeed, in a recent report, McKinsey & Co., the New York City management consulting firm, predicted the industry will be fundamentally different by the year 2000 [Fig. 1].

HIGH-END BATTLES. In an effort to secure their futures, Digital Equipment, Hewlett-Packard, and Silicon Graphics all made stabs at leadership in the workstation market. But Sun Microsystems fought hard to retain its dominance. At the end of 1992, HP and Digital were showing systems whose central processing unit (CPU) chips were ahead in raw performance. In the light of Sun's multiprocessing innovations, however, and IBM's concentration on pushing workstations into commercial as well as engineering applications, some questioned whether these chips alone would provide enough of an edge to ensure success.

The rivalry flared up most fiercely on Nov. 10, when Digital, HP, and Sun all held press conferences in honor of new workstations. Digital Equipment Corp., whose headquarters are in Maynard, Mass., announced systems based on its first home-grown commercial reduced-instruction-set computer (RISC) chip. The 64-bit Alpha processor had bowed earlier in the year [*IEEE Spectrum*, July, pp. 26–31]. As promised, the Alpha-based systems covered a broad range, from desktop to data center. DEC used the lower-speed, 150-MHz version of the chip in its series 300 model 500 AXP workstation, initially reserving the higher 200-MHz versions for its series 10 000 mainframes.

Richard Comerford Senior Editor

The desktop model 500s that began delivery in November had ratings of 74.3 SPECint92 and 125.1 SPECfp92 (integer and floating-point SPECmarks, based on a 1992 suite of programs for measuring workstation performance). An entry-level system was priced at US $41 195. To keep the DEC installed base of customers happy, the initial systems had VMS operating systems; OSF/1 systems will not be delivered until this March.

While DEC had the lead in delivered performance by year-end, Hewlett-Packard Co., Palo Alto, Calif., expects this quarter to start shipping a still faster workstation. Unveiled on Nov. 10, the model 735 runs HP-UX, HP's version of Unix, and performs at 80.0 SPECint92 and 150.6 SPECfp92. A typical configuration will cost $37 395. To leapfrog HP's system, which uses a 99-MHz PA-7100 RISC processor, DEC would need at least a 180-MHz Alpha chip and in fact has said it plans interim upgrades to its workstations this year. Thus the battle between DEC and HP for supremacy in single-processor workstation performance will intensify in 1993.

Earlier, in May, Sun Microsystems' subsidiary, Sun Microsystems Computer Corp. (SMCC), Mountain View, Calif., had led the pack with its Sparcstation 10, which also broke new ground by including an interface to the integrated-services network (ISDN). The workstation's "engine" is the SuperSparc chip, designed jointly by Sun and Texas Instruments Inc., Dallas, Texas. While the initial version lacks the raw horsepower of the HP and DEC RISC chips, the SMCC systems could be configured with one, two, or four processors, each capable of 58.1-SPECint92 and 71.4-SPECfp92 performance. A two-processor, model 52 workstation costs about $40 000. It remains to be seen if parallel processing suits the workstation environment and whether others will follow Sun's lead in this respect.

> **HIGHLIGHTS**
>
> **Success:** Apple Computer Inc. sold 400 000 PowerBook portable computers within nine months of their introduction, earning US $1 billion.
> **Shortfall:** Cost-effective technology for handwritten data entry via pen computing remained elusive.
> **Notable:** Sun Microsystems Computer Corp. introduced the first commercial parallel-processing desktop workstation, the Sparcstation 10.
> **Newsmakers:** Preparing for a new era in computing, Digital, IBM, and others in their class restructured their companies.

LOW-END PUSH. But SMCC's November announcement was aimed not at high-end workstation competitors, but at the PC. Based on another new TI-and-Sun RISC design—the 50-MHz microSPARC—SSMC's Sparc classic is a $4295 workstation. Besides running Sun's Solaris 2.1 operating system, it gives users a 15-inch color monitor, 16M bytes of RAM, 207 megabytes of disk storage, and performance better than 486-based PCs: 26.4 SPECint92 and 21.0 SPECfp92.

Low-end workstation performance is part of IBM's 1993 game plan, too. At the Unix Expo held in New York City last September, IBM announced that new low-end 200-series RS-6000 workstations would use the single-chip version of the Performance Optimization With Enhanced RISC (Power) architecture, being jointly developed with Motorola Inc., based in Schaumburg, Ill. Those workstations, slated to appear in the first half of 1993, will be the first to use the new chips. At the show, Big Blue admitted that the mainframe era was over and that 1992 had seen the workstation market shifting from being mainly engineering/scientific to being at least half business.

Silicon Graphics Inc. (SGI) kept control of its workstation CPU destiny by acquiring another California company, MIPS Computer Systems Inc. of Sunnyvale, early last year. Itself located in Mountain View, the company was thus free to increase its lead in graphics performance. This it did in July by pushing down the low end for high-performance graphics with its IRIS Indigo workstation (entry-level price: $12 485). It also reinforced the high end of its line with the Reality Engine. This complex multiprocessing graphics/display subsystem brings to SGI's Crimson and Power series of workstations outstanding interactive visual simulation. Since SGI plans to concentrate on the technology applications of its systems from now on, one can expect to see more in the way of high-performance workstations in 1993, as well as high-performance RISC chips.

Critical for all workstation companies will be the adoption of their basic processor

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architecture by others. Here Sun is by far the leader. Not only is TI enhancing the Sparc architecture, but a host of other semiconductor companies are producing Sparc chips. On the systems side, Cray Research Inc., Eagan, Minn., is developing a superserver based on Sparc and many companies are building portable Sparc-based systems.

IBM has built in acceptance of its Power architecture by teaming up with Apple and Motorola. As for SGI, it now has many agreements with companies to develop chips based on the MIPS architecture. Further, the graphics language it developed has become an open standard.

In July, HP licensed Winbond Electronics Corp., Hsinchu, Taiwan, to manufacture and sell PA-RISC chips for high-volume products. Digital, though it has yet to obtain the commitment of a large semiconductor manufacturer to fabricate Alpha-based chips, does have two renowned computer manufacturers—Olivetti and Cray Research—building Alpha-based systems.

EXPERT OPINION: New ideas will fuel real advances

TOM LYON

Every engineer has come to expect that each year computers will get faster, smaller, and cheaper. But has computing matured to the stage that these are the only changes to expect? What of new functionality, new concepts? Engineers do expect more, both because of dissatisfaction with the way things are and because we believe that no product remains the same in the face of advancing technology. So what advances are likely to impact our computers?

In processors, 1992 has seen the advent of commercial 64-bit processor architectures—the MIPS R4000 and the DEC Alpha. However, substantial software support for 64-bit architectures may be a long way off; even basic questions concerning language support for 64-bit quantities have not been answered by industry consensus. Ultimately, though, many expect the 64-bit addressing support in this new generation of processors will result in important software advances, just as the transition from 16- to 32-bit architectures enabled virtual memory systems.

'The convergence in parallel-processor workstations of affordable hardware and mature programming techniques promises new levels of application performance.'

Last year also saw the first volume production of multiprocessor desktop systems. Larger systems of this kind have been around for many years. But the convergence in parallel-processor workstations of affordable hardware and mature programming techniques promises new levels of application performance—both in throughput and responsiveness.

An interesting new measure of processors gained great importance this year—MIPS per milliwatt. While power consumption has always mattered in battery-powered laptops and palmtops, it is also becoming an important consideration in the design of any system. Cooling processors running at hundred-megahertz clock speeds is a major challenge, and although the trend toward 3-V logic helps a lot, it is not a long-term fix.

There was frenetic activity in laptop/palmtop/nomadic/personal digital assistant (PDA)/pen technology, but no clear winners. However, the pen computing movement of last year fizzled this year, as shown by Momenta's demise. Many now believe that, while pen computing will survive in some niche, it will be a decidedly different one, with decidedly different applications, from the niche occupied by the PC-clone laptops.

The niche structure of the handheld computing market may be pervasive: a general-purpose device may simply not be shaped properly to be effective for any one thing. Pen pads, calculators, pagers, and cellular phones all tend to have characteristic shapes. The challenge is not how to replace these devices, but how to bring them together into a way that makes sense.

Perhaps the most important technology to emerge from the frenzied laptop world is the PC Memory Card International Association (PCMCIA) bus. It defines those pocket-sized cards originally meant to replace floppies but now capable of general-purpose I/O. Everything from micro-sized hard disks to radio links to network connections to processor accelerators is planned for the PCMCIA form factor. Also important is the fact that this bus will be supported not just in PC-compatible systems but also with other processor and operating system architectures. It could become more popular than the floppy for cross-platform information interchange.

Multimedia technology advanced impressively. High-quality audio I/O, compact-disc ROM drives, and ISO's JPEG still-image-compression standard are being implemented for the consumer market, while the scalable nature of the nearly completed ISO MPEG II standard promises to bring full-motion video to many PCs and workstations in the next few years.

Nevertheless, to move beyond timeless "edutainment" applications of multimedia, into applications that require the synthesis, analysis, or simply communication of time-critical information will require more processing power and system support facilities than are yet practical. Fortunately, support for multimedia in networks seems to be evolving. The widespread availability of an integrated-services digital network (ISDN) outside the United States and the stabilization and harmonization of the ISDN standard worldwide make it the most attractive means of integrating wide-area data, voice, and low-rate video for computing systems.

For high-quality multimedia, or any high-bandwidth data communications, asynchronous transfer mode (ATM) technology has burst out of its home in the broadband ISDN telephony community and looks like the leading candidate for next-generation local-area networks (LANs). ATM's wide-area network (WAN) heritage removes most geographic limitations from LANs. Further, its simple, scalable nature promises to do for networks what RISC did for processors—allow hardware to easily exploit advances in very large-scale integration. Of course, as with reduced-instruction-set computing (RISC), this benefit is not entirely without cost, in the form of control of software for ATM. The clear distinction between the control and data functions of ATM is key to its performance advantages over traditional computer networks.

Wireless networking is another technology maturing rapidly to service the needs of portable computing. The spread-spectrum technology originally developed for military use is seeing widespread adoption in other products, and its development is being encouraged by regulatory bodies such as the U.S. Federal Communications Commission. Leverage of low-cost components built for celllular telephones also gives a boost to wireless computer networks.

However, potential users of such networks are rightfully reluctant to adopt them until their privacy needs are met. Sadly, the U.S. government's policies (set by the National Security Agency) effectively prohibit the export of most products that use encryption technology. Ultimately, I believe the attempt to ban encryption technology will be as ludicrous as outlawing ink—both are too cheap, too available, and too essential to be regulated.

The opening up of the Commonwealth of Independent States (CIS) is revealing a parallel universe of computing technology. Everything from compilers to circuit boards was developed in the old USSR under different constraints, a different infrastructure, and a different technological history. Many companies are eagerly teaming with CIS technologists to see how these ideas can be applied to western products.

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To survive in the future, apparently, a workstation company will have not only to capture a chunk of the market for its own products, but also to "sell" the basic architecture to merchant semiconductor producers as well as system makers.

How interesting it is to compare this approach to Intel's. While workstation companies eagerly look for others to produce chips based on their designs, Intel works ardently through the courts to prevent its designs from being used by others.

But after all, Intel's supremacy in the PC market is well established. Admittedly, computers based on Intel's 80X86 architecture seemed headed for a price/performance collision with RISC machines when 1992 began, but by mid-year all that had changed.

PC = PRICE CONFLAGRATION. Last year, the face of the PC world, too, was reshaped. Dell Computer Corp., Austin, Texas, was the first to recognize that PCs had become a commodity and so required new marketing techniques. With mail-order sales methods and unrivaled phone-support of customers, the firm cut the cost of doing business and passed the savings on to consumers. In reaction, Compaq Computer Corp., Houston, Texas, which had headed into the RISC arena in 1991 with the Advanced Computing Environment (ACE) Consortium, in 1992 pulled back to concentrate on its core PC business and adopted direct-sales techniques. Late in the year, IBM also fought back with a new line of low-cost PCs and reportedly had begun to recapture market share.

For PC manufacturers, the best technology news was that Intel would not deliver its next-generation chip until some time in 1993. (Code-named P5, the IC is officially christened Pentium, because a name can be copyrighted, unlike 80X86.) That makes it possible to recoup investments in developing 486 systems before those systems become obsolete.

Now that desktop PC systems have become a commodity, however, interest is skipping ahead to portable systems, which still command a premium and which keep shrinking in size and weight.

BRIEFCASE OFFICE. In 1992, the hottest portable group was the 215-by-280-mm notebook computers. But right on their tail was the subnotebook. This class includes computers measuring about 180 by 255 mm, weighing around a kilogram, and equipped with keyboards, albeit with minuscule keys. With its PowerBook, Apple proved that traveling Macs are in demand.

Subnotebooks, as well as palmtops like the HP95 from Hewlett-Packard, spurred several developments among peripherals. Last year it seemed as if 2.5-inch hard-disk drives would set the lower limit in dimensions for a while, but no sooner could they store a decent amount than overall dimensions began to shrink again.

Early in the year, the credit-card–sized 1.8-inch drive from Integral Peripherals (IP) Inc., Boulder, Colo., sent a slew of drive manufacturers back to their drawing boards. Fuji Electric has linked up with IP to produce drives, Nippon Steel joined with Western Digital to produce 1.8-inch disks, and IBM Japan unveiled its version. But in June, HP wowed the industry with a matchbook-sized 1.3-inch drive. (For the future, AT&T Co.'s new magnetic storage technology promised even denser disk media.)

Japanese makers of flash memory chips were reportedly stunned by the moves. They had expected that, by the late 1990s, pricing due to volume demand would let flash memory compete directly with hard disk drives. But with a 1.8- or 1.3-in. hard drive, flash memory's speed/density is less of an advantage and it may never reach the necessary volume.

HP made more waves in printers, with the small Deskjet it introduced in October. The 2-kg portable unit measures only 310 by 65 by 146 mm, about half the volume of a notebook PC. IBM also introduced a printer system geared to the portable market.

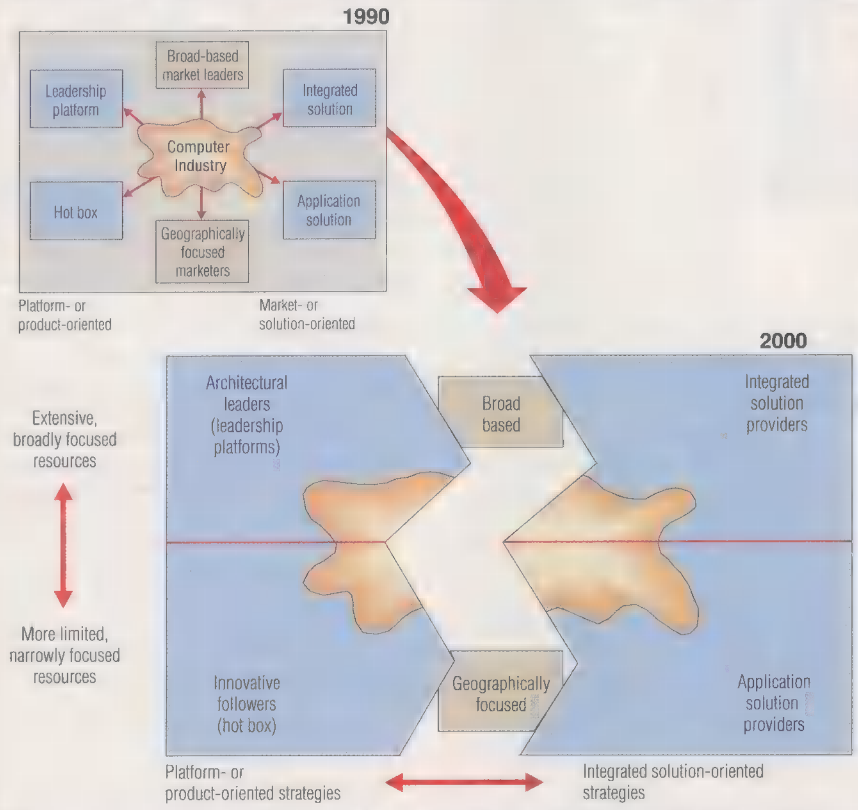
It was also a year in which the PC Memory Card International Association (PCMCIA) format for peripherals was widely adopted. At the November Comdex in Las Vegas, Nev., over 30 products based on the PCMCIA were introduced, including flash memory, disk drives, coprocessors, and network connections.

But Comdex did not signal that keyboards would disappear immediately. Pen computing was hard hit as some of its major proponents stumbled and fell. The most hurtful event occurred in late summer, when Momenta Corp., Mountain View, Calif., filed for bankruptcy protection after using up over $40 million in venture capital. Demand for its $5000 pen-and-keyboard system failed to materialize; in addition to being bulky and requiring custom software, the system failed to recognize some users' handwriting.

IBM's Thinkpad 700T also has sold only hundreds of units since its introduction in April. Quoted in an Oct. 6 article in the *New York Times*, Bruce Claflin, general manager of IBM Personal Computer Co., stated, "We don't see pencentric computing as being a ubiquitous horizontal market at this time."

During the same period, Dataquest Inc., San Jose, Calif., was scaling back its estimate of the 1992 market for such systems; it first projected sales of 300 000 units, then of 200 000, and most recently 77 000. Apple Computer Inc., Cupertino, Calif., unveiled plans for a pen-based handheld computer dubbed Newton earlier in the year but has since indefinitely postponed any introduction of the actual systems.

Sometime soon, no doubt, some journal will ask, "Is pen computing dead?" The answer is no. But it will take longer than many people thought to create a useful, affordable pen computer. To bring expectations for Newton more into line with reality, doubt that there is a near-term consumer market



[1] Because competition is shrinking the margins for error in business decisions, the structure of the computer industry is changing, according to McKinsey & Co., New York City. Whereas companies once embraced numerous areas—from high-end platforms to targeted applications—now they are focusing on distinct segments.

Hewlett-Packard Co.

[2] To exploit the potentials of multimedia, Hewlett-Packard Co., Palo Alto, Calif., created an integrated environment for work groups called MPower. It lets users manipulate essential multimedia data types—audio, still image, and video—and share work by e-mail, fax, or printing.

for such systems was reportedly expressed by John Scully, Apple chairman and chief executive officer, during an industry conference in September.

For pen computing to be widely accepted, reasonably priced computers will have to rapidly recognize any person's normal handwriting and translate it into ASCII characters or geometric shapes of use in documents, commands, or programming. Anyone who has worked on optical character recognition technology knows that this is no simple task.

Overcoming those obstacles, however, will create a vast new market. As things are, it takes less time to write a name, address, phone number, or an appointment in a daily organizer with a pen than to type it into a palmtop computer with its Lilliputian keyboard. On the other hand, today's paper-based personal organizers cannot make a laser printer address Season's Greetings cards, download recent sales data via modem into a spreadsheet, or automatically remind you that a meeting with a key client or a spouse's birthday is next Monday. Until electronic data can be easily and reliably entered and manipulated with a handheld stylus—or by the spoken word—a commuting computer will require a usable keyboard that limits the system's minimum size.

Many companies—Apple, IBM, AT&T, and Motorola, to name a few—are now trying to develop technologies that will realize a new world of what are called personal communication systems or personal digital assistants. These are pocket-sized computers that rely on wireless communication to make them eminently usable. This year's acceptance or rejection of new products will help define just how this technology will evolve.

DEFINING MULTIMEDIA. Some rationality gracefully entered the multimedial arena in October as 11 firms—whose areas of expertise include computers, consumer electronics, cable TV, communications, and capital—formed the first multimedia alliance, First Cities. The companies were Apple, Bell Communications Research, Bieber-Taki Associates (a venture capital group), Corning, Eastman Kodak, Kaleida Laboratories, North American Philips, Southwestern Bell, Sutter Bay Associates, Tandem Computers, and US West.

Refreshingly, Bruce Sidran, executive director of the alliance, said that First Cities' first job would be "to determine whether there really is a marketplace out there." If so, in 1994 First Cities will wire about 10 000 homes for interactive multimedia in an unidentified city in the United States.

Multimedia is a huge technological concept, so huge that it embraces all forms of human communications and places high performance requirements on computer and network hardware and software. Thus, developing it to the point where it is truly useful will not be simple.

Assembling the hardware needed to develop multimedia programs—digital-signal processing cards, stereo speakers, video controllers, compact-disc ROM—on one's own can be difficult, but the problem is not insurmountable. Furthermore, last year, several companies, including IBM, have introduced personal computers that meet Microsoft's definition of the Multimedia PC.

Now, software tools are needed to make use of the hardware, and some authoring tools are beginning to appear. For example, the MPower system unveiled by Hewlett-Packard in November [Fig. 2] was designed so that several individuals—say, a group of photographers, musicians, writers, and sales people—could work jointly on a project to develop a multimedia sales demonstration.

Having interactive tools that communicate efficiently will be essential to creating useful multimedia programs. The tools and standards needed are moving into place. ◆

Software

- ***A rough year for software engineers***
- ***Unix invades China***
- ***A new software notation***
- ***The top-down approach***

Last year ended an era of prosperity for software and computer companies. In the United States, the software industry was shaken by one of the largest economic tremors in industrial history due to ■ weak economy and the dramatic shift from minicomputers and mainframes to PCs and workstations. Some of the big players are now shrinking even faster than they grew. DEC, Hewlett-Packard, IBM, Prime Computer, Unisys, and Wang (which entered Chapter 11) have all cut back employment. Even the wildly successful Microsoft has warned industry analysts it will not grow as vigorously as before, although it is one of several major software vendors that plan to expand in 1993. Expansion is also in the cards for outsourcing software groups like Keane Associates and Computer Power. Naturally, there will be start-up companies, but it would take more than 500 start-ups to absorb the people who have left Wang and DEC alone.

A lackluster global economy has weakened other industries that employ countless software professionals—airlines, telecommunications, insurance, banking, and defense contractors. In the past, software personnel often were shielded from cutbacks and layoffs by the fact that software is a prime contributor to corporate operational efficiency and critical to many new products. But when firms dwindle swiftly and significantly, or go out of business, everyone is affected.

Thus 1993 is likely to be a tough year, because the degree of downsizing in so many different business sectors has created major dislocations in employment. But in the remainder of this decade, software employment will increase. Software's role in business will grow, as downsizing cuts out layers of management and some administrative personnel. The software content of all kinds of products, from automobiles to watches, will grow at faster rates.

OH, WHAT ■ LOVELY WAR. Apart from Nintendo, no software was more entertaining in 1992 than operating systems. Everyone watched the battles between Windows, OS/2, and all the fine young Unixes. In the past year, two new versions of Microsoft's Windows—version 3.1 and Multimedia Windows—have appeared, as has the latest (2.0) version of IBM's OS/2. While Windows garnered the largest chunk of the market, with well over 10 million copies installed, OS/2 ramped up to over ■ million copies in short order. Yet while Windows 3.1 did provide some advances in multitasking, OS/2 seems to offer superior performance in this area.

There is no question that, in Apple's world, the System 7 created the biggest stir in 1992. It has both its boosters and detractors. Those fortunate enough to have had seamless integration of System 7 into their working environments have been impressed with its great aptitude for multitasking; others have found that the system can unexpectedly end a session without indicating in detail the nature of the problem.

In the Macintosh "space" (as marketers now term an application area in which ■ system dominates), System 7 may well mark the end of the "You don't have to understand anything about computers to use them" approach, long the trademark of Apple Computer Inc., Cupertino, Calif. While a properly installed System 7 environment can be ■ dream to use, not every user will be able to set one up correctly. Specialists in properly setting up Macs are growing in number, and many computer-savvy Mac users can recall midnight calls from panicky graphics designers whose Macs have "lost" ■ layout.

From Microsoft Corp., Redmond, Wash., the response to multitasking is Windows NT, which is now due some time late in the first half of 1993. Just as DOS had IBM as its champion, Digital Equipment Corp., Maynard, Mass., will work with Microsoft to put Windows NT on DEC's new Alpha RISC platforms sometime in 1993. By advancing from the PC to the workstation world, Windows will enter into combat with Unix. Of course, Digital is not yet fully siding with Windows NT; it plans to have OSF/1 ready for Alpha first, in March of this year, before Windows NT.

Excitement about future operating systems—such as Windows NT and the OS being jointly developed by IBM Corp. and Apple Computer Inc.—prompted *Byte* magazine to ask "Is Unix Dead?" "No," says most of industry. Indeed, Unix may well become the operating system used by the most people in the world, after the November deal in which Unix Systems Laboratories Inc., Summit, N.J., edged out Microsoft to supply operating system technology to the People's Republic of China.

Further, Unix-based operating systems gained ground throughout 1992, as AIX, HP-UX, and versions of SVR4 were delivered on workstations moving into the business sector. According to data presented by IBM at Unix Expo in New York City last September, Unix is shifting from being primarily a technical/engineering operating system to one that serves the commercial sector too. IBM said that the mix of sales of Unix platforms was split evenly between technical and commercial activities in 1992, although Gary Eichhorn, workstation systems group general manager for Hewlett-Packard Co., would disagree. His argument is that trying to create a program to predict macro and micro economic trends with great accuracy is more in the nature of a technical than a commercial endeavor.

For heterogeneous computing environments (where computers from different suppliers must work together), Unix is far ahead of other operating systems in terms of scalability. No other operating system covers the full range of systems, from supercomputers to PCs. Indeed, the need to support distributed computing environments is making major suppliers, such as Hewlett-Packard and IBM, cooperate in ways that would have been unimaginable five years ago.

Moreover, standards such as Posix are proving the feasibility of that application interoperability (the ability of a program to run on different, standards-compliant versions of the Unix operating system). This assures users that their applications will not keep them from making the economically correct platform choice.

But from a PC perspective, switching over to Unix can be daunting. The Unix range offered for PCs runs the gamut from AIX to Xenix—and they are not compatible. If such systems are to move into the PC market,

HIGHLIGHTS

Success: Distributed computing is making unexpected collaborators out of a number of erstwhile competitors.

Shortfall: Deliveries of Windows NT may not begin until the second quarter of 1993.

Notable: The function-point metric for evaluating software is gaining acceptance.

Newsmakers: IBM's OS/2 ramped up sharply, but did not overtake Windows 3.1.

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their vendors will have to agree upon standards that provide the same degree of compatibility as DOS and Windows do. For Windows NT, on the other hand, it will be an uphill battle to encompass the range of systems that Unix already covers.

Undoubtedly, other operating system contenders will appear in the coming years who will gather a following and find niches in the marketplace. Like the genie of Aladdin's lamp, the user community promises untold wealth to whoever sets them free—from having to worry about operating systems. System features being worked on by groups like the Computer Framework Initiative Inc., Austin, Texas, will influence the shape of future operating systems. So, too, will the need for security and virus protection, which are already being incorporated into system software that will appear this year. So operating systems will continue to be a source of religious fervor and entertainment for years to come.

Another source of religious fervor is software engineering. While still in its infancy, software engineering is moving rapidly to become more of an engineering discipline, as some of the elements that have been missing or incomplete received more attention in 1992.

One of the most essential elements of science and engineering, the ability to accurately measure software in ways that are generally agreed upon, has been given much more study. The oldest metric for measuring software quality and programmer productivity is based on a counting the lines of source code, or simply, LOC. However, this metric has never been standardized for any of the over 400 different programming languages that exist. No one can quantitatively answer how a line of C source code relates to a line of Fortran. Further, as Capers Jones, chairman of Software Productivity Research (SPR) Inc., Burlington, Mass., points out, "for some languages, such as graphic icons or spreadsheet formulas, the whole idea of a line of source code is a very poor fit." Nor can any single metric be used to measure tasks such as requirements generation, specification, and user documentation—all essential elements of software quality and productivity and, in some cases, dominant ones.

Owing to these shortcomings, a newer metric—function points, or FP—has been gaining in popularity and will receive more attention at software conferences throughout the year. Function points are based on five aspects of software: inputs, outputs, inquiries, logical files, and interfaces.

FP has behind it a not-for-profit organization called the International Function Point Users Group (Ifpug) whose membership has been growing rapidly since its founding in 1986. One of the largest software organizations in the United States, its membership includes many of the Fortune 500 companies as well as Government and military agencies; IFPUG affiliates exist in Australia, Brazil, Canada, the Netherlands, New Zealand, and the United Kingdom. With its ability to

EXPERT OPINION: Software productivity under the microscope

CAPERS JONES

Software competition is becoming globalized. In terms of the number of applications developed and installed, the United States has been the world leader in software production since the industry began. Software Productivity Research (SPR) Inc., Burlington, Mass., estimates that through 1992 about 40 percent of all the software operating in the world originated in the United States. In the United States itself—the world's largest market for software—SPR estimates that over 95 percent of the applications now installed and operational originated there. Lest the United States become smug about these statistics, it should be remembered that there was a time when statistics like these also applied to the automotive industry.

Software is an attractive product for many countries. Its development consumes very little in the way of natural resources (other than paper, where software is a major consumer). The value per shipped ton of software applications is the highest of any manufactured product, so software is an attractive business for countries—such as India, Japan, Russia, Singapore, and Taiwan—which are geographically remote from the United States and other target markets. International outsourcing of software is starting to become a topic of some concern to the United States.

This year, India and Russia will actively pursue out-sourcing arrangements and contracts for development work with U.S. software consumers. As chairman of a software production company, I have been contacted personally by representatives of both Indian and Russian groups soliciting outsource contracts. Both countries have academic training in software engineering that is about on a par with the United States. The salary levels, however, are as little as one-tenth of U.S. norms. Neither country's economy is large enough to employ all the software professionals on indigenous projects, so international outsourcing is being actively encouraged by both governments, and by trade associations as well. International outsourcing is only beginning in 1993, but its potential for moving U.S. jobs and funds out of the country is real.

'While the United States may export programming jobs, Europe seems to be making it more difficult for the rest of the world to export software to it.'

SPR has analyzed the risk of international competition, and concluded that systems and commercial software have the greatest risks. The military is unlikely to outsource critical defense applications overseas, certainly not to Russia. The management information systems (MIS) domain normally requires close and daily contact between clients and developers, so geographic separation is a problem. However, systems products—such as PBX, process control, and embedded applications—do not depend upon close proximity between developers and users.

While the United States may export programming jobs, Europe seems to be making it more difficult for the rest of the world to export software to it. As Europe began a rough and jolting trip toward economic unification last year, one tenet was the adoption by members of the European Economic Community of a number of standards created by the International Standards Organization (ISO).

Of particular concern to software are the new ISO quality standards, numbered 9000 through 9004 but usually just called "ISO 9000." On the surface, these standards are intended to ensure the quality of software and engineered components. Unfortunately, the standards themselves are not very modern. The quality concepts they include appear at least 10 years behind the state of the art. Further, to date there has been no empirical evidence presented that the ISO certification actually leads to products with higher quality than noncertified products.

Still, in order to market software and other engineered products in Europe, they must be ISO-compliant. For software, gaining ISO certification requires on-site visits by inspection personnel, who review the quality related aspects of the development processes used.

One view of the ISO certification process and the ISO standards themselves is that they represent a hidden tax against foreign companies, and are a barrier to international trade, erected to slow U.S. penetration of European markets. This view may not be true and the ISO standards may be what they are presented to be—a sincere attempt to improve quality. However, three things are certain: the ISO certification process is fairly expensive, is slow, and—like it or not—must be endured.

Capers Jones (M) is chairman and founder of Software Productivity Research Inc., Burlington, Mass., and the author of numerous books on programming productivity and software metrics. In previous executive positions with IBM and ITT Corp., Stamford, Conn., he was heavily involved introducing modern techniques for programming.

provide useful metrics, FP is likely to become an important metric for software engineering.

SEEING SOFTWARE. Another important basic tool needed for software engineering discipline is a system of notation; the ability to graphically present information is fundamental to engineering.

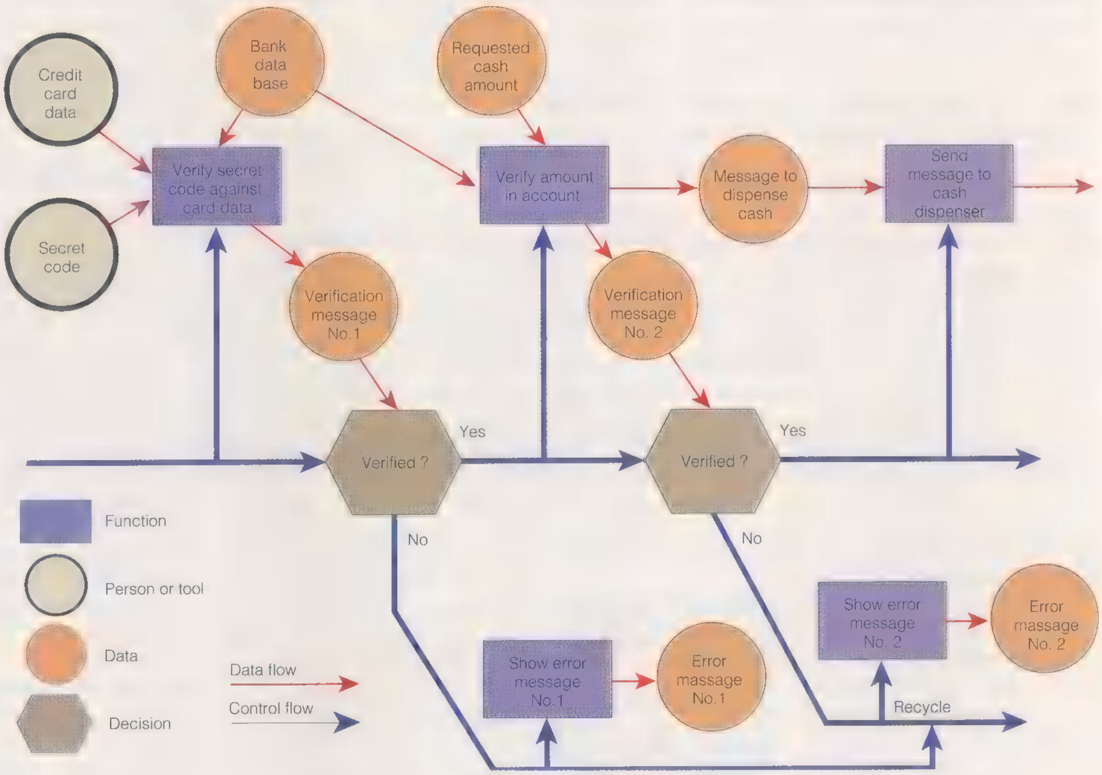
Traditionally, there have been numerous schemes for graphing software. But traditional methods leave much to be desired in an era when software systems have become immense and complex, when object-oriented methods are becoming widely used, and when the need to quickly understand how the modules of a system interact is critical to good design. The usual graphing methods are not equipped to give a clear picture of the control and data flow organization of programs. As a result, new techniques are being developed by the industry.

One example of a notation designed to help visualize the operation of modern software systems was recently discussed by CAE-Link Corp., Binghamton, N.Y. (As yet, it has no formal name.) Among the benefits of the notation are its ability to clearly indicate program control flow and, separately, data flow [Fig. 1], its handling of subdiagrams, and its ability to make the concepts of object-oriented programming easy to grasp and use [Fig.2].

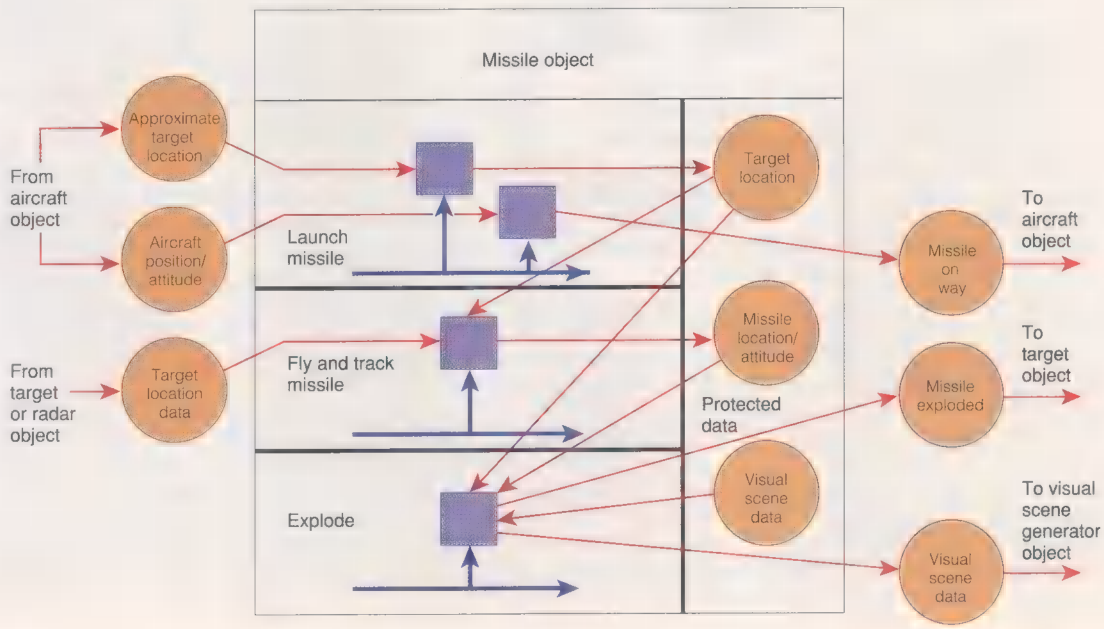
This year, as the need to communicate software concepts clearly and quickly is recognized, more tools will provide support for new graphical notations. As users gain experience with them, it is likely that a standard will emerge for a new notation.

LOOK AT OO GO. A third basis for modern engineering practice is the widespread availability of standard, reusable components from which to build systems. For the first time in its history, software is beginning to acquire that strength, in the form of the object-oriented method and with the aid of the Ob-

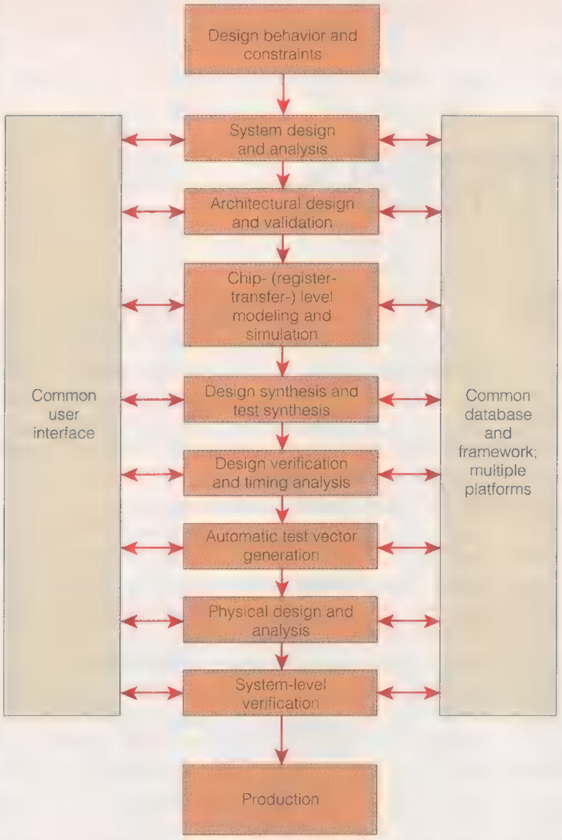
[1] New notations for software should provide software engineers with a way of visualizing all the elements and relationships in a program. The drawing of a teller machine program clearly indicates the differences in data and control flow. Only after a process is complete does the control flow to the next function.



[2] The representation of a software object for an aircraft-launched missile shows how an object can consist of multiple processes and, further, how it may own its own data. The processes shown here could also be objects that would be shown in greater detail in a subdiagram.



ject Management Group, Framingham, Mass., an international organization aiming to provide a common object-oriented application framework.



[3] Automated top-down design requires a smooth, bidirectional flow of information in electronic form from one tool to the next, so that it becomes easy to see what effect changes in any stage will have on the original intent of the design and, conversely, to make any concept changes waffle through the various layers to the final product.

The object-oriented programming community is now well over the 100 000 mark, and growing at something like 20 percent a year. According to SPR Inc., the measured productivity results for object-oriented programming languages are quite good. While the current U.S. software productivity average is about 5 function points per staff month, the mode among object-oriented projects is close to 15 function points per staff month, although published results are still somewhat sparse and may be biased.

In other areas of application for object-oriented techniques—such as object-oriented analysis and design and object-oriented databases—not enough projects have been completed and measured to draw firm conclusions. As yet, accurate, quantified case studies do not exist, but preliminary indications are favorable.

Not surprisingly, activity in the area of object-oriented programming skyrocketed in 1992. To mention just a few of the significant events, giant Computer Associates, Islandia, N.Y., entered the C++ market last September through the acquisition of the well-known Glockenspiel Ltd., Dublin, Ireland. In July, database leader Sybase Inc., Emeryville, Calif., merged with Gain Technologies Inc., Palo Alto, Calif.; the latter company used its objected-oriented technology to develop Gain Momentum, a general-purpose multimedia application development environment unveiled last year. Already, Gain has signed agreements with IBM, Solbourne Computers, and Sun Microsystems to provide software for their workstations, and it is working with Matsushita to develop new object-oriented multimedia technology for HDTV.

One aspect of object-orientation widely demonstrated in 1992 was its ability to simplify the integration of programming tools, particularly when companies support a common interprocess communication regimen. Interactive Development Environments, Cadre Technologies, Frame Technologies, Interleaf, McCabe & Associates, and Softool agreed to support the CASEVision development environment from Silicon Graphics Inc. (SGI); all the firms support SunSoft's ToolTalk—object-oriented software for interprocess communications.

Pure Software Inc. and Mercury Interactive Corp. signed a joint technology agreement last September to integrate their object-oriented development and test products. Pure Software Inc., Los Altos, Calif., provides a unique tool called Purify that checks object code at the instruction level for illegal memory access errors and memory leaks. It then identifies the cause in the original source code, thus simplifying software debugging. For its part, Mercury Interactive Corp., Santa Clara, Calif., provides XRunner, which allows users to create record-and-playback tests.

Object orientation also brings another benefit—the ability to create sophisticated applications for specialized domains without being a programmer. One example of a code-free object-oriented environment is Magic 5.0 from Magic Software Enterprises Inc., Irvine, Calif. Using Magic 5.0, users quickly implement complex business applications that can run on numerous, heterogeneous Unix platforms and access numerous different databases and standard-query-language (SQL) servers. MicroStep, from Syscorp Corp., Austin, Texas, is a similar, PC-based system, and code-free programming systems are beginning to appear at a rapid rate, again underscoring the need for new metrics.

ENGINEERING APPLICATIONS. Integrating complex Electronic Design Automation (EDA) applications in a heterogeneous environment became easier this year, too, as more EDA companies began to comply with the standards and guidelines put forth by the Computer Framework Initiative Inc., Austin, Texas. But users are still finding it necessary to perform integration tasks themselves, and it slows down the adoption of broad frameworks.

On the other hand, tool frameworks—suites of tools focused on a particular task—are making life simpler for engineers. With that in mind, EEsof Inc., Westlake Village, Calif., created Series IV, the first tool framework for high-frequency analog design. Series IV integrates new and existing EEsof tools into a single environment that lets engineers make decisions at a system level, not only at the circuit level.

EEsof Inc.'s top-down tools are part of a general trend that swept through the EDA industry in 1992. Mentor Graphics Inc., Beaverton, Ore., also focused on top-down design with its Top-down Design Solver and top-down design libraries for simulation and synthesis, as did Cadence Design Systems Inc., San Jose, Calif., with its Systems Workbench.

What these companies have seen is that the design process is moving up the scale [Fig. 3]; the people who are ultimately designing application-specific ICs are not traditional IC designers but systems engineers set on ensuring that the system (rather than IC) functions are properly implemented. Now that techniques such as logic synthesis and the use of high-level hardware description languages are becoming firmly established, engineers can concentrate more on high-level concerns than on the details of the implementation.

One of those high-level concerns is understanding what variables determine an optimum design. While most technical professionals have heard of statistical process control (SPC) and total quality management (TQM), they seem to be unaware of the most necessary tool for successfully implementing SPC and TQM: design of experiments (DOE). This technique for gathering and analyzing empirical data enables engineers to pinpoint the important variables in a process.

Last October, an organization to help educate engineers about DOE was created by BBN Software Products, a division of Bolt Beranek and Newman (BBN) Inc., Cambridge, Mass., and a supplier of DOE software tools. Called DOE/Direct, it is serving as a national clearinghouse for information about DOE training and information programs. It also provides access to a network of independent DOE consultants.

Other groups, such as The Software Productivity Consortium, Herndon, Va. and The Software Engineering Institute, Pittsburgh, are offering programs to educate users on how to improve software quality. Such programs should help any company become more competitive and efficient in these difficult times. ◆

Large computers

- Workstation nets vie with supercomputers
- Amid mainframe decline, machines [redacted]
- More massive parallelism
- Japan's Fifth Generation miscarries

Just four or five years ago, the large computer market gloried in consistent growth, high profit margins, and a comfortable pace of technological advance—one that let vendors predictably improve upon certain established architectures. With price tags deep in the six figures or higher, these machines are not for everyone. But for some applications, at some companies, few would think of using anything else.

What [redacted] difference a half-decade makes.

Recession and technological progress, plus the move toward so-called open systems based on industry-standard operating systems, have roiled the industry. Where a mainframe once reigned, a network of personal computers served by [redacted] mid-range computer may now rule. Similarly, where once a minisupercomputer or a vector-equipped mainframe was *de rigueur*, a cluster of workstations based on extremely powerful and relatively inexpensive microprocessors, running the Unix operating system, might now hold sway. In [redacted] industry where no phenomenon seems *bona fide* until it has [redacted] buzzword, the trend is known as "downsizing."

"One of the things I've been noticing is that some of the vector machines are being replaced by networks of workstations," said George Gardner, an analyst at Arthur D. Little Inc. in Cambridge, Mass. "People are linking RS-6000s [the IBM workstation] to get similar performance."

Downsizing is hardly a new trend. But combined with the economic recession—which has made countless companies defer or cancel plans to either buy [redacted] new mid-range or mainframe computer or trade up to a more powerful one—the effect on the industry has been serious. In fact, scattered predictions of the mainframe's death were heard again last year. They echoed the forecasts of the vector supercomputer's imminent replacement by massively parallel systems, popular wisdom a year ago (and to this day, too, in some quarters).

Lately, though, cooler heads seem to be prevailing, and many industry experts seem less ready to write off the mainframe. "While it is a dynamic, I don't see it as the wave ready to crest," said Steven Josselyn, a computer industry analyst at International Data Corp. (IDC) in Framingham, Mass. "A lot of issues need to be resolved before you can start implementing [powerful systems based on microprocessors] in [redacted] commercial environment."

Glenn Zorpette Senior Associate Editor

MARKET TRANSFORMATION. Even these experts, though, agree that formidable forces are afoot. The market at the end of 1992 differed noticeably from 10 or 12 months earlier. Among the key developments:

- For the first time ever, revenues from the sale of computers all over the world declined in 1991, according to the market research firm Dataquest Inc., San Jose, Calif. The largest decline was in mainframes, followed by mid-range systems and personal computers. Only workstations showed modest growth. Further declines were predicted for 1992. All kinds of computer companies, from Amdahl, in Sunnyvale, Calif., to IBM reported losses on their mainframe lines. Maynard, Mass.-based Digital Equipment Corp., for example, reported [redacted] US $260.5 million loss in its fiscal quarter ended last Sept. 26.
- No new large systems emerged from IBM Corp., following far-reaching mainframe introductions in the autumns of 1990 and 1991. "They didn't see the demand out there," Josselyn said.
- Wang Laboratories Inc., of Lowell, Mass., and Alliant Computer Systems Corp. of Littleton, Mass., filed for protection under Chapter 11 of the Bankruptcy Code. Wang, a maker of mid-range systems, said it would lay off nearly half of its 13 000 workers. Alliant made minisupercomputers, some coupled with high-end graphics systems, and had just brought out a massively parallel line when it halted normal operations.
- A survey by *Nikkei Computer*, a Japanese industry publication, found that less than half of current mainframe users in Japan intend to stay with mainframes when their current systems become obsolete. A shift to network-based distributed data processing—downsizing, in other words—was cited as the key factor behind the finding.
- Control Data Corp., Minneapolis, Minn.—one of the most important pioneers of the mainframe in the late 1950s—split into Control Data Systems Inc., which sells and services computers and integrates computer hardware into larger systems, and Ceridian Corp., formerly the parent company of Control Data Systems. Ceridian's primary businesses are audience ratings of television and radio programs, payroll processing and other employer services, and Government computer work. The spinoff company, Control Data Systems, has partnerships with NEC, Volkswagen, Intergraph, and Silicon Graphics, which owns 10 percent of the new company.

> **HIGHLIGHTS**
>
> **Success:** Hitachi Ltd. introduces S-3800 supercomputer with peak processing rate of 32 billion floating point operations per second; Fujitsu announces massively parallel VPP 500, in theory capable of 355 gigaflops.
>
> **Shortfall:** Japanese Fifth Generation project comes to [redacted] close without achieving many of its objectives.
>
> **Notable:** In a slumping market for large computers, IBM introduces no new mainframes.
>
> **Newsmaker:** Cray chief executive John A. Rollwagen announced a joint $70 million development contract with the U.S. Department of Energy.

Such evidence of the mainframe's enervation notwithstanding, some did debut last year. Digital Equipment, for one, led forth three series of mid-range and mainframe machines, the VAX 4000s, 7000s, and 10 000s. The company's last foray into the mainframe world, the VAX 9000, was not an unqualified success. But where the 9000 line kept to mainframe tradition, with its emitter-coupled logic processors and elaborate cooling mechanisms, the top-of-the-line 10 000s are a different species of large machine. Based on [redacted] small number of very powerful CMOS microprocessors, the 10 000s offer roughly twice as much performance for [redacted] given price as the 9000s, according to Digital.

The CMOS microprocessor, called NVAX, implements the VAX architecture in 1.3 million transistors. The chip, with 0.75-μm features, operates at 3.3 rather than 5 volts, [redacted] first for Digital. At 91 MHz it provides about 35 times the performance of Digital's once ubiquitous VAX 11/780, the mid-1980s' vintage superminicomputer whose one-million-instruction-per-second performance was the industry standard.

Both the 7000s and 10 000s can be built around one to six of these chips, but the 10 000s have more powerful I/O capabilities, uninterruptible and back-up power supplies, and [redacted] more extensive service contract. The 4000s are also based on NVAX processors, but with clock speeds of 63–83 MHz. The three models in this line perform from 16 to

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32 times faster than the VAX 11/780.

In November, Digital announced a unique option whereby the NVAX microprocessors in the machines could be quickly replaced with the company's Alpha microprocessors. Introduced by Digital in February 1992, the Alpha is an advanced, CMOS, reduced-instruction-set computer (RISC) chip that Digital is selling on the merchant market [''DEC bets on Alpha,'' *IEEE Spectrum*, July 1992, p. 26].

Since the I/O structures and memories of the 7000s and 10 000s were designed to accommodate either NVAX or Alpha, changing from one microprocessor to the other will involve simply swapping microprocessor boards, according to Daryl Long, product manager for Digital's Alpha/VAX system group. Of course, converting existing VAX software will not be quite so simple, but at the November introduction, Digital announced a series of software tools designed to facilitate the conversion process.

Another company bidding for more of the slack mainframe market is Hitachi Data Systems, which makes IBM-compatible mainframes. Last June the Santa Clara, Calif.-based subsidiary of Hitachi Ltd. in Tokyo unveiled its GX series, including eight new models, mostly lower- and middle-range mainframes. The company redesigned its EX line somewhat to serve as the high end. Altogether, the series covers a fairly wide segment of the performance range of the IBM ESA/390 architecture.

Meanwhile, the maximum number of processors in conventional mainframes is creeping upward. Fujitsu introduced the first eight-way processor in 1990; Amdahl delivered mainframes based on eight-way processors last year, and some expect IBM to introduce a high-end, water-cooled, eight-way processor in its ES/9000 family later this year. ''IBM tells us they have a 10- or 12-way running in the lab,'' said IDC's Josselyn. ''But they're still trying to work the bugs out of having that many processors running, while still keeping a single system image and keeping the overhead [communication and coordination among processors] down.''

Although IBM introduced no mainframes in 1992, the company did vastly improve upon its Enterprise System Connection (Escon), the optical-fiber-based connection architecture introduced in 1990. Escon links a mainframe with peripherals, like mass-storage units or printers, up to 9 km away. It may also connect one cluster of mainframes to another.

Originally, one communications channel had to be dedicated to every link—between a printer and a mainframe, for example. Now, with what IBM calls Escon Multiple Image Facility, the channels can be shared across multiple devices, greatly reducing the costs.

EXPERT OPINION: So many architectures, so much fanfare: what's a user to believe?

HELEN M. WOOD

We keep being told the traditional mainframe is dead. And now there are rumblings that conventional supercomputers will soon follow. Should we all trash our machines and rush out to buy clusters of workstations or exotic, massively parallel processing (MPP) systems? Perhaps we should just sit back and wait until the market ''settles down''—if indeed it ever will.

One thing is certain—this is a time of dynamic change in the large systems arena. ''The era of the alternative mainframe has arrived,'' declares James L. Cassell, vice president for large computer strategies at the Gartner Group in Stamford, Conn., and it is difficult to argue with him. This year saw new offerings with mainframe- or even supercomputer-class performance at dramatically lower cost. Examples included Hewlett-Packard's HP 3000 Corporate System, Kendall Square Research's KSR1, and Digital Equipment's VAX 10 000. Apparently, other vendors, too, are positioning themselves to change their offerings. Hitachi has licensed HP's RISC architecture and Fujitsu, similarly, Sparc technology from Sun Microsystems.

'Rather than reflexively acquiring another mainframe, I will pay serious attention to alternative platforms.'

Besides doing more for less money than traditional mainframes, today's alternative platforms are scalable and based on open-systems principles. Vendors are responding with conviction to user demands for lower price/performance ratios and for open-system technology. Indeed, some analysts now speculate that all major vendors will replace their traditional mainframes by the mid-1990s.

Clearly, the transition to a completely new environment for users of large-scale systems will not happen overnight. New applications can obviously latch onto the alternative mainframe much more quickly than can those vested in so-called ''legacy'' systems—traditional machines based on proprietary architectures and instruction sets. With over two decades of operational software and databases residing on these mainframes, the huge base of business applications will be slowest to migrate to new platforms. So we can expect to see traditional mainframes around for the next five to ten years.

It is common knowledge that advances in software lag behind those of hardware. Nowhere has this been more painfully obvious than in supercomputing. Yet there are signs of progress to report in both operating systems and programming languages. Work is progressing on a standard, parallel version of Fortran, and there are signs of similar movement in C. Complementing those developments are efforts aimed at producing tools for the development of parallel software. Such developments will, in time, enlarge the number of application programs able to exploit parallel architectures. But of even greater interest to all who have suffered the trials of software and data conversion when moving to new systems, these developments herald a shift away from specialized environments.

On the operating systems front, Unix is the bandwagon of choice for supercomputing—both vector and parallel. Whether AT&T, Berkeley, or a Posix-compliant subsystem, this trend is visible in the efforts of Cray Research, Digital, the European Commission's Esprit effort, and others. All three Japanese supercomputers now support a version of Unix. Coupled with the work in programming languages, we can look forward to a time when applications will be moveable not only between similar architectures, but among radically different ones as well. Still, much work remains before users can expect to routinely achieve a significant percentage of the theoretical peak performance of conventional or parallel supercomputers while running real-world programs on them.

Cassell predicts that the ES/9000 will be the last water-cooled mainframe from IBM. Those of us who have invested in this system should take heart, however. An aggregate peak performance of 2.67 billion floating-point operations per second makes the model 9000 with integrated vector facilities quite respectable when compared with a Cray Y-MP or other traditional supercomputers such as those of Fujitsu and NEC. Recent operating system improvements in MVS/ESA and expected enhancements to AIX/ESA for Unix users will improve CPU utilization and performance.

Nevertheless, in the next two years, rather than reflexively acquiring another mainframe as my data-processing workload soars past 400 million instructions per second, I will pay serious attention to alternative platforms. With today's average selling price for a conventional mainframe in excess of $50 000/MIPS, other users will undoubtedly do likewise—and so hasten the demise of the old warhorse.

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"What it has done is gotten a lot more people interested in Escon architecture, which is a key to growth for IBM," IDC's Josselyn observed.

In one of its first acts as a company, Control Data Systems introduced a line of midrange computers last September. The 4680-300 series of servers was designed for use with large databases or in other data-intensive applications, according to the company. Based on the MIPS R6000 processor chip set produced by MIPS Computer Systems Inc. (now part of Silicon Graphics Inc.), the machines are said to execute 86 million instructions per second (MIPS) with one processor, and 344 MIPS with the maximum complement of four.

MORE MPPs. Massively parallel processors (MPPs) continued their quest for a bigger share of the high-performance computer market—which in 1991 was worth a little less than $1.5 billion in the United States alone, according to the Smaby Group Inc. That year, according to the Minneapolis, Minn., market researcher, MPPs garnered just over 18 percent of the market.

One long-awaited machine that finally debuted was the KSR1 from Kendall Square Research in Waltham, Mass. The machine can have up to 1088 nodes, each with up to 32M bytes of memory. These memories are physically distributed among nodes but are nonetheless logically shared—that is, they are managed as if they were pieces of a single, large, continuous memory.

An arrangement of this nature may be the next wave in MPPs. Cray Research, Convex Computer, and Tera Computer are all planning to use this sort of memory model in forthcoming MPPs ["The power of parallelism," *Spectrum*, September 1992, p. 33].

Last year, hefty contracts from the U.S. Department of Energy and its laboratories gave huge boosts to two more companies designing or marketing MPP systems. In July, the Oak Ridge National Laboratory in Tennessee contracted with Intel Corp.'s Supercomputer Systems Division in Beaverton, Ore., for a 512-node MPP called Paragon XP/S. By the time it is completed, probably early next autumn, it will have cost approximately $40 million.

Last November, Intel unveiled a scaled-down version of the 512-node machine at Oak Ridge. Each of its nodes is based on two of Intel's own i860 XP microprocessors. In the final version, each node will be based on five of the microprocessors, and the machine as a whole is expected to have a peak processing rate in excess of 100 billion floating-point operations per second (gigaflops). In both versions, one microprocessor in each node communicates with other nodes, and the rest compute.

CRAY'S ENERGY CONNECTION. Cray Research, meanwhile, will be working with the Department of Energy's Lawrence Livermore National Laboratory in Livermore, Calif., and the Los Alamos National Laboratory in New Mexico under a three-year program announced last October. The cost of the program, $70 million, will be borne by both the Department of Energy (DOE) and Cray; but the actual details were not released. In a sense, the project will formalize relationships already established by Cray, which had been working with Los Alamos on MPP architectures even before it launched its own project.

A highlight of the Cray-DOE collaboration will be the installation, by the end of this year, of a trio of MPP systems, one each at the two laboratories and at Cray's Eagan, Minn., headquarters. The three will be linked by high-speed networks so as to give a researcher at any of the locations access to some substantial portion of their combined computational power.

At the program's announcement in Chippewa Falls, Wis., Cray chief executive John A. Rollwagen said the basic intent is to accelerate the introduction of Cray's MPP hardware and software into the user community. Also present was Energy Secretary James Watkins, who gave almost a campaign speech in the feisty last days of the presidential campaign, calling the accord "among the most important cooperative research agreements ever to be executed by the DOE." Earlier, Cray's MPP program had been awarded a $12.7 million, three-year grant by the Defense Advanced Research Projects Agency in Arlington, Va.

Just three days before the Chippewa Falls affair, Cray revealed more details of its MPP system. The company had previously disclosed that the machine, code-named T3D, will be based on Digital Equipment's Alpha microprocessor, use technologies from the Y-MP and C90 lines for packaging, cooling, and I/O, and have memory that is physically distributed but logically shared. Last October, Cray added that the T3D processors will be interconnected in a torus topology that minimizes the distances, and hence communications delays, between processors [see diagram, p. 37]. Communications are routed through a high-speed bidirectional switch, without distracting the arithmetic processors.

Like Intel's Paragon and another MPP, the CM-5 from Thinking Machines in Cambridge, Mass., Cray's machine will support both multiple- and single-instruction, multiple data (MIMD and SIMD) programming styles. The T3D was designed to be coupled with any Cray vector supercomputer in the Y-MP line, so the machine will also mix vector and MPP programming styles.

Other MPP vendors are also combining vector and parallel computation; Thinking Machines, for example, began delivering vector units for its massively parallel CM-5 system last autumn. These vector units, which attach to each processor in the machine, boost the peak double-precision processing rate from 5 to 128 million floating-point operations per second (megaflops) and the memory bandwidth (the maximum communications rate between the processor and its memory) from 128 to 512 megabytes per second.

JAPAN'S FIRST MPP. Fujitsu is taking a similar approach in its Vector Parallel Processor (VPP) 500, whose surprise September announcement stirred more than the usual comment and interest. The numbers claimed by Fujitsu for this machine—the first commercial Japanese MPP—are barely believable: each processor will have a peak processing rate of 1.6 gigaflops, and there can be from seven to 222 of them, for an aggregate theoretical maximum processing rate of 355 gigaflops. Although Fujitsu expects to deliver the first VPP500s next autumn, it was not clear that the most powerful configuration would be available immediately.

Besides these peak rates, the VPP500 sports another impressive number: the maximum configuration would cost in the neighborhood of $125 million, a very exclusive neighborhood indeed. So far, no unclassified supercomputer user has ever paid more than $40 million for a supercomputer.

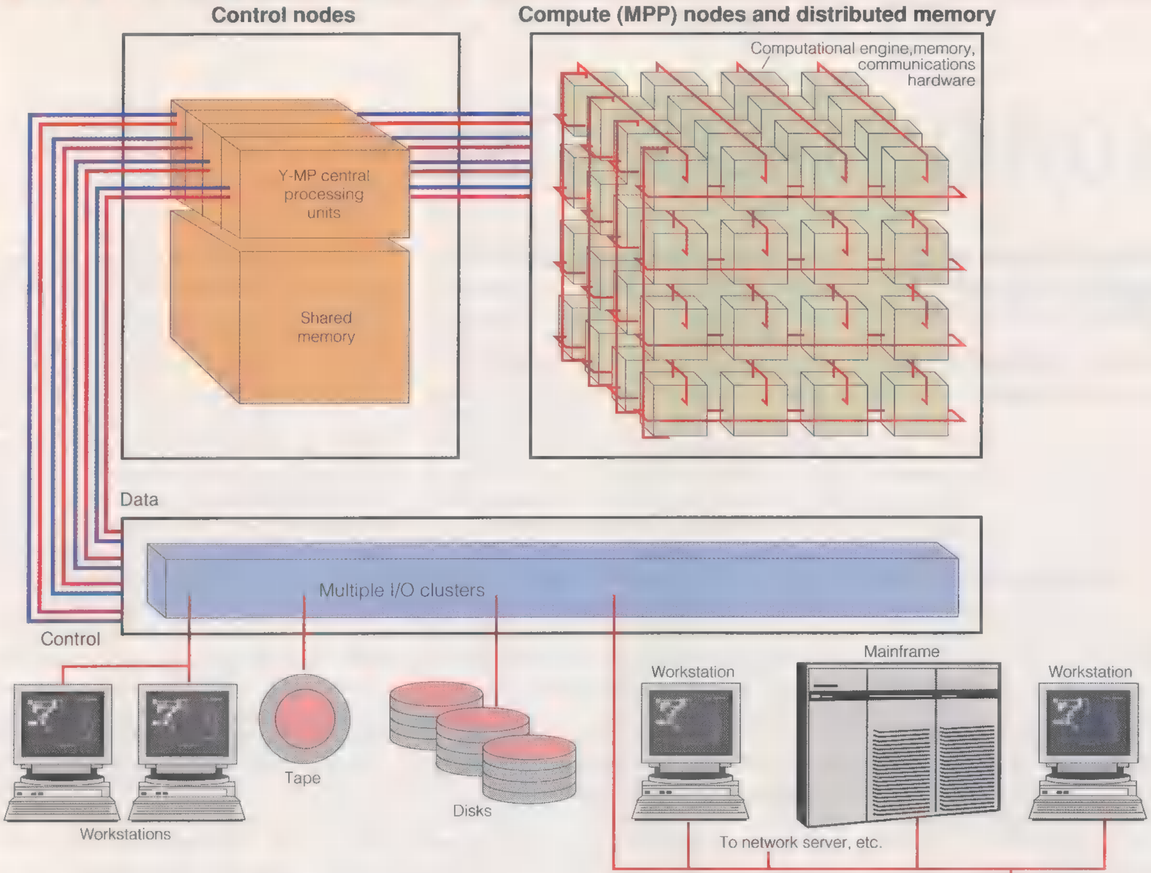
Even so, if its performance claims for the VPP500 withstand scrutiny, Fujitsu may be out in front in the race to deliver a machine that can sustain a trillion floating point operations per second (teraflops) on real programs. This is the goal of most supercomputer makers. Indeed, Fujitsu already "expects to achieve the 10-teraflops level by the end of the decade," to quote a recent company release.

The 1.6-gigaflops rate claimed for individual VPP500 processors is more than 10 times as fast as anything in any of today's MPPs. For comparison, a fully configured eight-processor Cray Y-MP—the company's state of the art until the first C90s were delivered last year—had a peak of 2.67 gigaflops. The very high peak of the VPP500's individual processors will be achieved with a combination of gallium arsenide and BiCMOS. Each processor couples a vector processing unit with a RISC processor. The paired processors will be linked together by a crossbar network.

There was also at least one SIMD arrival last year: the MP-2 from Sunnyvale, Calif.-based MasPar Computer Corp. Maspar is the largest of the few companies still pursuing the SIMD approach. There are five configurations of the MP-2, with 1024 to 16 384 processors. A 4096-processor machine, installed at Iowa State University's Ames Laboratory, has on occasion exceeded a gigaflops, according to MasPar. That machine lists for a little more than a half million dollars.

The only conventional, vector-style supercomputer to bow last year was Hitachi Ltd.'s S-3800. Its maximum of four processors each have a cycle time of 2 ns and a peak processing rate of 8 gigaflops, for a theoretical maximum of 32 gigaflops. The next highest aggregate peak, 24.6 gigaflops, belongs to NEC Corp.'s SX-3. Such exalt-

Cray's massively parallel processor (MPP)



ed processing rates are never actually reached in practice, but are sometimes approached in repetitive, compute-intensive benchmarks, like the Linpack (which solves a system of linear equations) with a huge number of coefficients and unknowns.

Thirteen months ago, Cray Computer Co., Colorado Springs, Colo., was dealt a serious blow when Lawrence Livermore National Laboratory decided to terminate a $30 million contract for the company's first system. Cray Computer then said it would seek a partner to help it market a four- or eight-processor version of its planned 16-processor system, based on advanced GaAs semiconductors. In November, the company announced it would work with Thinking Machines on an installation at the National Center for Atmospheric Research in Boulder, Colo. If funding can be secured, the two will set up a system combining Cray Computer's Cray-3 vector machine and Thinking Machines' massively parallel CM-5. The move was interpreted as a response to rival Cray Research's plans for its T3D system, also a vector-parallel machine.

BEST-LAID PLANS. Last year saw the conclusion of the Fifth Generation Computer Systems Project in Japan, which popular opinion has already branded one of the most spectacular failures in computing research since the Iliac IV at the University of Illinois in the 1960s. The project was launched in 1982 amid much fanfare to develop highly parallel computers that would run knowledge-based and artificial intelligence software. The implicit goal was to leapfrog U.S. computer makers into what was then perceived as the next wave in computing. A consortium called the Institute of New Generation Computer Technology (ICOT) was formed to do the R&D.

Then things went agley. The hoped-for 1000-processor system was never built, nor was much hardware that could be commercialized, for that matter. In July, at the final conference, ICOT demonstrated a few of the five machines it constructed, which strutted their stuff by analyzing protein and amino acid sequences, proving mathematical theorems, and rendering legal opinions based on precedents. The largest one built during the $400 million project had 512 processors and achieved about 100 million logical inferences per second (megalips).

Writing in the September *Spectrum*, David K. Kahaner, a leading expert on Japanese computing, said the project's enduring legacy will be its software. All of it has been made available to the public, he noted, and many young Japanese have been rigorously trained in symbolic computation, parallel computing, and knowledge processing.

No sooner had the Fifth Generation project been concluded than Japan launched another grand research consortium: the Real-World Computing Program (RWC). This $500 million project will also be a decade-long effort, focusing on the use of massively parallel and other advanced computing technologies to mimic human thought processes in complex tasks. Extensive work on neural networks, optical computing, and data-flow computer architectures is also planned.

The RWC will involve a looser confederation of research projects than did the Fifth Generation, however. And unlike previous Japanese consortia, which were strictly limited to Japanese participants and whose results were closely guarded, the RWC is open to others.

So far, though, the U.S. government has blocked participation by U.S. companies, ostensibly because it has no policy on the support of research being done by non-U.S. governments. Several industry observers believe that the delay also stems from fear that advanced U.S. technology could be misappropriated. As a possible first step, however, the United States plans to allow cooperation in the prototyping of optical computing components. ◆

Telecommunications

- **CATV companies carry phone service**
- **Phone companies convey television**
- **Wireless personal communications win go-aheads**
- **Erbium-doped fiber amplifiers installed in longest repeaterless link**

For the last few years, marketing reports and newspaper articles have whipped up much excitement by predicting a day when desktop and portable computers, telephones, facsimile machines, cable television, CD ROM, audio receivers, and other devices in the office and home would all be connected globally.

After this long drumroll, 1992 may well be remembered as the year when all those communication technologies around the world actually began merging—not just through prototypes and technology trials, but in commercial systems. And a dark horse is shaping up to be one of the leaders in the merging and provision of telephone, data, and multimedia services: cable television.

For the longer term, the widely touted personal communications services got a big boost. In this vision of worldwide wireless communications, individuals anywhere, indoors or out, can make or receive calls on a pocket handset.

Meanwhile, in the more "traditional" business of long-haul optical-fiber systems, several advances were made. Revolutionary system architectures also appeared as erbium-doped optical-fiber amplifiers moved out of the laboratory into production and deployment.

CABLE TV OFFERING PHONES. The local and long-distance telephone companies have long sought to provide multimedia services through the phone companies' integrated-services digital network (ISDN). The channel standards were set years ago, and more recently consensus was reached on the synchronous optical network (Sonet) standard for sending digital data on the optical fibers.

Although ISDN has become operational in selected areas around the world, it has mainly been made available to businesses ["Data communications," pp. 42–45]. One of the circumstances delaying its introduction into homes, particularly in the United States, has been the old, narrow-band twisted pair of copper wires that make up the last few hundred meters into a home. Some estimates of the cost to replace all these local loops with broadband fiber have run as high as US $200 billion.

Trudy E. Bell Senior Editor

In many nations, however, the broadband coaxial and fiber cables of cable television companies already enter more than half the TV homes in the country (as high as 88 percent in Belgium, the highest penetration in western Europe, and 62 percent in the United States, where cable plant passes 90 percent of TV households).

The original cable TV networks were equipped to carry only a few two-way services, and none with the complex switching of telephone systems. But in recent years, cable TV providers have realized it is probably faster and cheaper to retrofit their broadband plants with switches and to negotiate linking their systems with those in neighboring franchise regions than it is for telephone companies to replace all the copper wires with fiber. That advantage gives the cable TV companies the chance to tackle the phone companies on their own turf.

Britain is particularly fertile for cable-TV experimentation with telephone services. Cable and Wireless PLC, the London-based international telecommunications group, announced in November that it was investing £30 million in Montreal-based BCE Inc.'s UK cable-TV interests. These are beginning to provide local telephone service to residences and small businesses. BCE is Canada's largest company; formerly known as Bell Canada Enterprises (no relation to the U.S. Bell companies), it owns the local telephone provider, Bell Canada, and more than half of the telephone equipment maker Northern Telecom Ltd., Mississauga, Ont.

BCE Telecom International Inc., a subsidiary of Bell Canada, controls East London Telecommunications, owner of six cable franchises in the London area covering about 630 000 homes, according to a report in the London-based *Financial Times*. Last month, BCE Telecom began building facilities for a combined telephone and television service in the London borough of Redbridge. Overall, BCE has cable franchises in Britain covering 1.8 million homes and 120 000 businesses. So far only a few thousand customers are using BCE's phone services, but the company plans to expand.

In 1989, BCE acquired a 23 percent stake in Videotron Corp. Ltd., the London-based cable-TV arm of Canada's second-biggest cable operator. Videotron has 69 500 UK cable subscribers, of whom 2500 residential and 1000 business subscribers have signed up for phone service in its Southampton franchise. Videotron is looking to add telecom capacity to its south London networks before expanding into new markets.

What's more, Mercury Communications Ltd., London, the Cable and Wireless rival to British Telecommunications PLC (British Telecom), estimates it is selling about 10 000 cable phone lines a month, and that Britain could have more than 300 000 such lines in place by next year. Cable gives Mercury access to the local loop, which is otherwise dominated by British Telecom.

TELCOs OFFERING TV. Last June, the U.S. Federal Communications Commission (FCC), Washington, D.C., gave the go-ahead for the Bell regional holding companies to transmit television programming to homes over phone lines, although it still maintained the ban on the telephone companies' owning cable-TV companies or more than 5 percent of the programming producers. On the other hand, the phone companies will be permitted to offer menus, gateways, billing, and related services for video programmers.

In November, Bellcore Inc., the Livingston, N.J.-based research consortium for the Bell regionals, demonstrated a way that phone customers could get VCR-quality movies and other programs over the phone lines—including a remote control to pause the image, reverse it, or speed it forward. In this system, developed jointly with Bell Northern Research Ltd., Nepean, Ont., Canada, the video programs are digitized, compressed, and stored in a "video warehouse," a computer linked to the phone network. The full video can be sent over the regular narrow-bandwidth twisted copper pairs to most homes. The system is expected to be market-tested later this year.

Although the U.S. telephone companies are prohibited by law from owning and operating cable-TV systems in their own terri-

HIGHLIGHTS

Success: Wireless personal communications services win major approvals at the 1992 World Administrative Radio Conference and by the U.S. Federal Communications Commission.

Shortfall: Integrated-services digital networks (ISDN) grew more slowly than anticipated in the United States.

Notable: Erbium-doped fiber amplifiers go into service in longest repeaterless optical-fiber link.

Newsmakers: Cable television companies enter the wireline and wireless telephone business.

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tories, they are free to do so outside the United States. And many of them—including Nynex, Pacific Telesis, and U S West—are entering the cable-TV business.

U S West has a joint venture in Britain with Tele-Communications Inc. (TCI) (both companies are based in Englewood, Colo.). Known as TeleWest, the U.S. joint venture is now the largest single cable company in the UK. It is also offering phone service in certain areas. Between September 1991 and last October, TeleWest added 50 000 cable subscribers, for a total of 120 000. Its residential phone lines also went on growing, reaching 48 000 last September, and its business lines reached 14 percent of potential business customers, up from 9 percent the previous year. A small survey done by TeleWest indicates that subscribers who receive both phone and cable-TV services from the same company are less likely to "churn" (want to be disconnected from cable TV) than those who receive them separately.

EVERYONE GOES WIRELESS. Cable television firms are also rushing to ally with cellular and wireless communications companies, with the goal of competing with local telephone companies for major positions in the burgeoning personal communications services (PCS) business.

Last February, the 1992 World Administrative Radio Conference designated frequency bands for future mobile communications services. Particularly notable were provisions for such services to be handled via low-earth-orbiting satellites ["WARC's last act?," *IEEE Spectrum*, February 1992, pp. 20–33]. PCS also forged ahead in the

EXPERT OPINION: Boundaries between communications technologies are blurring

BENNETT Z. KOBB

In 1992 telecommunications and data communications grew steadily less distinguishable from one another—a trend that should accelerate in 1993 and beyond. Voice and images are coming to rely on digital transmission. Indeed, in paging, mobile telephony, new forms of satellite communications, and the burgeoning field of wireless personal communications services, messages are increasingly being transmitted as digital data. Moreover, the boundaries between video and telephone communications are also blurring.

'Cable-TV companies are up-and-comers in PCS technology, seeking alliances with other wireless companies to operate PCS systems in competition with conventional telephone companies.'

One action of note in the United States last year occurred in July, when the Federal Communications Commission (FCC) concluded that personal communications services (PCS) is a concept worth pursuing. The FCC proposed to allocate frequencies for deployment of several emerging technologies—including PCS—in the 2-GHz band.

The FCC also awarded "pioneer's preference" vouchers, which will later be exchanged for PCS licenses, to three companies (out of 56 contenders): American Personal Communications Inc., Washington, D.C.; Cox Enterprises Inc., Atlanta, Ga.; and Omnipoint Corp., Colorado Springs, Colo. The pioneer's preference is a rarely awarded and highly prized early assurance of a license grant, an advantage that could offer its winners head starts over competitors for local wireless service in market areas selected by the awardees.

Particularly interesting is Cox, a diversified firm with holdings in cable, broadcasting, newspapers, video rental stores, and other areas. Cable-TV companies are up-and-comers, seeking to operate PCS systems in alliance with wireless companies and in competition with the phone companies.

The other shoe is dropping in the form of "video dial tone," in which the FCC will permit local phone companies to deliver cable-like video services to customers. Telephone companies are still not permitted to own cable companies in their own operating areas or to perform the traditional video programming tasks of cable systems, but they will be permitted to offer menus, gateways, and billing and related services to video programmers.

The FCC's endorsement of the fledgling technology will not enable PCS to be deployed overnight. The 2-GHz band is already used in some locations by the microwave communications systems of railroads, electric utilities, and public safety agencies. Those incumbents must be compensated for their trouble in making technical changes to their stations where necessary.

This could present an expensive front-end cost to the PCS industry. Most of the approaches to this problem involve combinations of modulation techniques and frequency-agile PCS equipment that could "avoid" incumbent users, and conversion of incumbent microwave facilities to higher frequency bands.

Apple Computer Inc., Cupertino, Calif., proposed a "frequency optimization" plan that could be used to clear large segments of the 2-GHz band for emerging technologies. The plan, which Apple claimed could slash the cost of transition to emerging technologies, consolidates the loading of 2-GHz channels through retuning of stations.

Apple was a founder of the Wireless Information Networks Forum (WINForum), a new industry trade group composed of companies involved in low-power, unlicensed PCS applications. Participants in the group include AT&T, California Microwave, Digital Equipment, Ericsson, Hewlett-Packard, IBM, Motorola, NCR, Northern Telecom, Rolm, Rose Communications, Sun Microsystems, Tandem Computers, and Xircom.

The FCC initiated proceedings for another emerging technology, which it calls digital audio radio services (DARS). These services include digital sound broadcasting to the public via both satellite- and earth-based transmitters. It would allow existing AM and FM bands to carry compact-disc–quality sound.

Basing its proposal on decisions taken at the 1992 World Administrative Radio Conference, the FCC proposed in October to allocate the 2310–2360-MHz band to DARS. This band is currently used for aeronautical telemetry, a use that will be reaccommodated in 2360–2390 MHz.

For the private mobile "two-way" radio industry, the FCC sweepingly proposed to reduce regulations, consolidate services, and thus speed up the introduction of spectrum-efficient technologies. Under current channel formats, spectrum is scarce and services are running out of channels.

The FCC's "spectrum refarming" policy would reduce channel widths and transmitter power, increasing the number and availability of channels. Through a novel approach called "exclusive use overlay," the commission would offer exclusive rights to ranges of channels to entrepreneurs who promised to deploy improved technologies there.

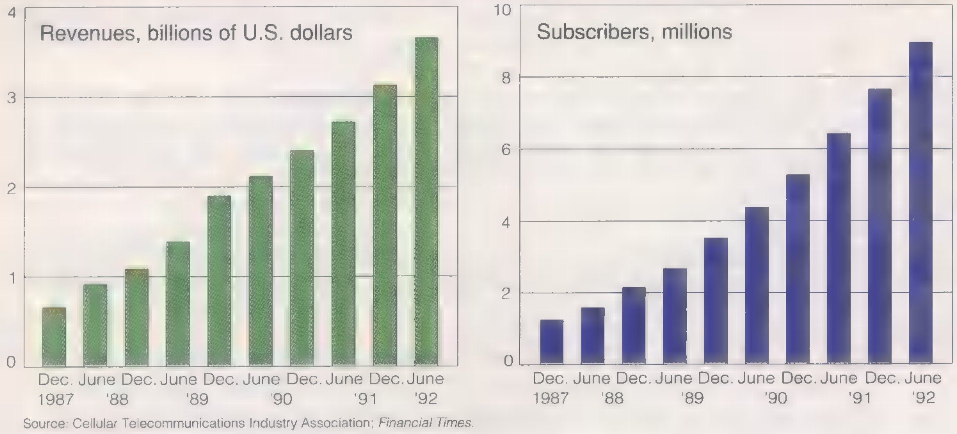
Wireless electronic mail also made gains this year, with the introduction of portable data communications products. One was Motorola's InfoTAC Personal Data Communicator, which attaches to laptop, palmtop, or pen-based computers.

Even the venerable Internet, the world's largest computer network, is becoming unwired. RadioMail Corp., Menlo Park, Calif., announced two-way connections between the Internet and wireless data and paging service providers.

Moreover, the FCC is now considering allocating additional spectrum in the 900-MHz band to wireless e-mail and advanced paging applications. It granted a pioneer's preference to Mobile Telecommunication Technologies Corp. (Mtel), Jackson, Miss., for its multi-carrier modulation technique and proposal for a nationwide wireless data network. Mtel's technique can transmit 24 kb/s in a radio channel 50 MHz wide.

Bennett Z. Kobb (M) is an Arlington, Va.-based consultant in radio policy and president of the Wireless Information Networks Forum. He served as editor of *Cellular Radio News*, *Personal Communications* magazine and *Federal Communications TechNews*, the first periodicals for the cellular and emerging spectrum-based technology industries.

Cellular telecommunications in the United States



[1] Cellular telecommunications in the United States nearly quadrupled in both revenues [left] and number of subscribers [right] between the end of 1987 and mid-1992.

United States with the FCC's allocation of frequencies in the 2-GHz band to the deployment of several emerging technologies, including PCS [''Boundaries between communications technologies are blurring,'' p. 39].

Cox Enterprises Inc., Atlanta, Ga., was one of three companies to which the FCC granted a coveted ''pioneer's preference'' voucher. This gives them the exclusive right to offer the technology in a certain geographical area. Among other things, Cox is one of the nation's largest cable-TV multiple systems operators.

In Cox's plan, PCS is wireless to the end user, who will carry the small PCS handset. But that handset will communicate to base stations connected to the cable-TV plant, acting as the backbone infrastructure and carrying the telephone signals through switching systems to their destination.

This kind of technology will allow cable companies into the local wireless phone business, bypassing the Bell lot entirely. The area awarded to Cox is San Diego, Calif.; elsewhere, the company would have to compete with many parties for PCS licenses.

Other cable TV companies getting into the PCS act include Cablevision Systems, Comcast (which owns cellular telephone networks in the United States and the UK), Time Warner Telecommunications, and Viacom International.

Moreover, the chief U.S. long-distance carrier AT&T Co. has jumped back into the local access business by buying a third of McCaw Cellular Communications Inc., the biggest U.S. firm in the wireless market. McCaw's cellular mobile-telephone network scoops in about 40 percent of the U.S. population—some 2 million cellular subscribers—and almost all the nation's largest cities.

The strategic alliance means that AT&T could connect local customers directly to its long-distance lines through the cellular network, bypassing the Bell regionals. If so, AT&T will be in direct competition with its former Bell operating companies for the first time since the Government-mandated breakup of the Bell system in 1984. (Although the court decree outlining the terms of the breakup—the Modification of Final Judgment—barred the Bell regionals from providing most long-distance services, it did not prevent AT&T from re-entering the local-exchange market, as long as it did not do so by buying back the regionals' assets.)

In another deal, MCI Communications Corp., Washington, D.C., announced in November that it would set up and manage a national consortium of companies with the goal of launching a new wireless network. With the blessing of regulators, the net could be offering PCS by next year.

WEST HEADS EAST. Ever since the unification of Germany and the breakup of the USSR, the nations of Eastern Europe and the Commonwealth of Independent States (CIS) have been seeking the support of the leading telecom companies in the industrialized nations. The promise: golden opportunities in providing the former Communist Bloc countries with modern phone systems. In all those nations, the infrastructure is poor; in CIS, for example, the average number of phone lines per 100 people is only 15, and Eastern Europe has even fewer.

Fastest-moving have been the mobile phone networks, which in a few months can be serving a broad area from just a few satellite antennas and base stations, without digging up streets to lay cables and fibers. Among those that have negotiated joint ventures with Eastern European and CIS telephone companies are Ameritech, AT&T, Bell Atlantic, Deutsche Bundespost Telekom, France Télécom, Nokia Telecommunications, PTT Telekom Netherlands, Telecom Denmark, and U S West.

MULTIMEDIA COMMUNICATION TAKES OFF. In multimedia communications, 1992 was critical for some enabling technologies. Video compression led to the introduction of AT&T's new Videophone 2500 (which in the 1990s may no longer be too far ahead of its time, as AT&T's Picture Phone was in the 1960s). It also led to video boards for computers (such as Cameo from Compression Laboratories Inc., Liberty Corner, N.J.), and computer access to stored video and images (such as data-voice-image–based, or DVI-based, systems from Intel Corp., Santa Clara, Calif.). Although these products are still in their infancy, they hint at things to come.

According to Sudhir R. Ahuja, department head of integrated computer/communication systems research at AT&T Bell Laboratories in Holmdel, N.J., multimedia is driven above all by new and powerful applications and services. Last year, multimedia entered computers mostly through training materials or presentation tools such as Persuasion by Aldus Corp., Seattle, Wash. Access to information and sound at the same time has led to multimedia mail systems such as NeXT Mail.

From the networking point of view, the biggest change to accommodate multimedia has been the support for signaling in the network and the addition of intelligence to the communication terminals. The first intelligent terminals introduced last year included the SmartPhone by AT&T and VoiceView by Raddish Communication. Those changes suggest that a future phone may be more like a personal computer, Ahuja observed. Indeed, that is the direction in which the Personal Communicator by EO Inc., Mountain View, Calif., is moving, for the tablet-like device combines a pen-based computer with cellular voice and fax capability.

This year, the biggest impacts are expected in the first real-time multimedia conferencing and PCS. Already many experimental conferencing systems are under trial at companies—Ultimedia at IBM, Rapport at AT&T Bell Labs, and Mermaid at NEC, for instance. All these systems are expected to become available in a couple of years over integrated-systems digital networks (ISDN).

FIBER AMPS ENTER SYSTEMS. Silica optical fibers doped with the rare-earth element erbium will amplify many wavelengths of transmitted light. Erbium-doped optical-fiber amplifiers went on developing rapidly last year. Several manufacturers, including AT&T Microelectronics, BT&D Technologies, Corning's Telecommunications Products Division, Italy's Pirelli, and Canada's JDS Fitel/Furukawa, either introduced or offered improved versions of erbium-doped fiber amplifier modules.

Typically the modules incorporate one or two packaged pump laser sources with associated control circuits, plus optical isolators; these reduce the effect of reflections on the erbium-doped fiber gain elements. The modules' small-signal gain (the power gain of the amplifier as the input signal decreases toward zero) typically ranges from 20 to 35 dB, with 3-dB optical bandwidths

that are 10–30 nm around a center wavelength of about 1.55 μm. Saturated output powers ranging from 5 to 15 dBm are also available. The modules represent a first step toward eventual standardization of fiber amplifier hardware and performance, similar to the standardization of Sonet or synchronous digital hierarchy (SDH) for compatible lightwave transmitters and regenerators.

AT&T is installing erbium-doped fiber amplifier modules in the world's longest repeaterless undersea optical-fiber system linking Ayia Napa on Cyprus with Nahariyya, Israel. The cable span is 261 km. To be completed and ready for service later this year, it will incorporate fiber amplifier booster modules, which are optical transponders between standard lightwave terminals (operating at 1.3 μm or 1.55 μm) and the repeaterless fiber link (operating at 1.55 μm). The module's erbium-doped fiber amplifiers boost the output of a low-chirp transmitter from –3 dBm (decibels below 1 mW) to a launched power of more than +13 dBm, eliminating the need for undersea repeaters. With one active and one spare fiber, the 622-Mb/s bit rate of the Cyprus-Israel system will allow the equivalent of 78 000 simultaneous conversations.

STRAIN IMPROVES PERFORMANCE. The active layers of multiple-quantum-well (MQW) lasers can be made of semiconductor compounds whose crystal lattices are slightly mismatched, and thus experience minute strain. Such strained lattices can give the lasers greater quantum efficiency and a narrower output spectrum than lasers made of unstrained MQW or bulk materials. Those properties improve system and device performance in several areas.

In lightwave transmitters, for example, strained MQW indium gallium arsenide phosphide lasers can produce light pulses at 1.3 or 1.5 μm with much less "chirp" (wavelength spread), so the pulses disperse less as they travel through the optical fiber.

In fact, according to N. Suzuki and G. Hatakoshi at Toshiba Corp. in Japan, calculations indicate that data could be transmitted at 10 Gb/s over standard optical-fiber links up to 1000 km long, using a directly modulated strained-layer MQW laser source. As a way of turning a laser on and off, direct modulation of the drive current is simpler and less expensive than techniques relying on external amplitude modulators such as titanium-doped lithium niobate waveguide devices. The approach is therefore attractive for high-bit-rate lightwave systems.

In addition, strained-layer MQW lasers can also efficiently emit light with 950–1050-nm wavelengths, which are inaccessible with non-strained-layer devices. For example, strained-layer MQW lasers made of alternating layers of InGaAs and GaAs can emit at 980 nm, where erbium-doped fiber amplifiers are efficiently pumped. Packaged 980-nm laser modules with maximum fiber-coupled output powers of 50–100 mW are now commercially available from Lasertron Inc., Burlington, Mass., and two Canadian companies, Seastar Optics, Sidney, B.C., and EG&G Canada Ltd., Optoelectronics Division, Vandreuil, Que. Moreover, a 980-nm strained-layer quantum-well device with a maximum output power of 380 mW at 25 °C and a lasing threshold of 17 mA was reported by NEC Corp. in Japan last year.

CHEAP CONNECTIONS. Optical communication systems generally employ individually packaged optoelectronic and electronic devices that are assembled on printed-circuit boards. "This conventional approach is unlikely to fulfill the high-density and low-cost requirements of emerging applications such as optical computer interconnects and fiber in the loop," observed Craig Armiento, research supervisor of the optical interconnects and packaging department of GTE Laboratories Inc., Waltham, Mass.

Many organizations are working on cost-effective means of packaging components with disparate physical, electrical, thermal, and optical characteristics. Basically there are two approaches, Armiento noted—monolithic integration of optoelectronic and electronic devices on a single chip in the same material, and integration of differing components or chips on a common platform to make a hybrid optoelectronic IC.

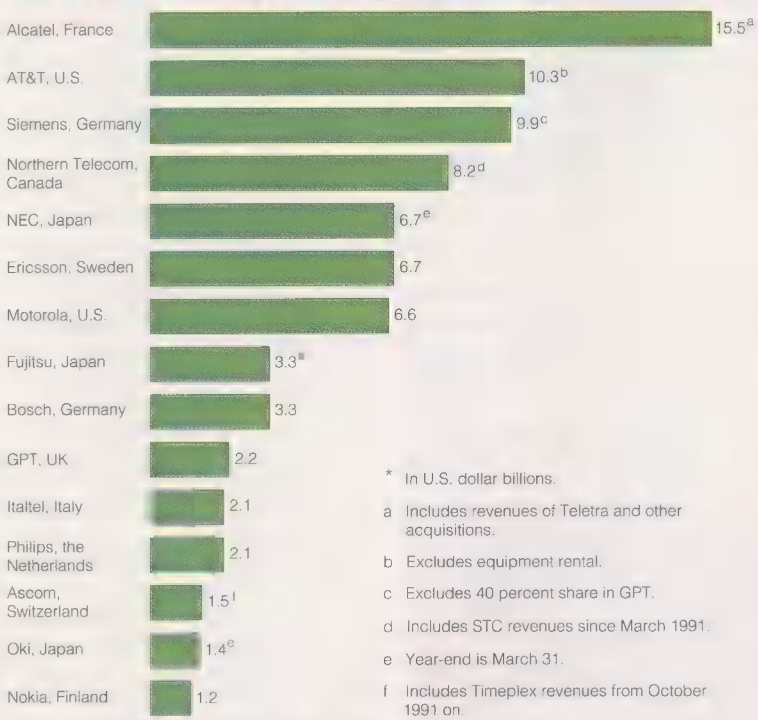
In Armiento's view, the hybrid approach is more flexible, because it can combine individually optimized components. It can also incorporate nonsemiconductor components such as optical fibers, minimizing the major cost of optoelectronic systems: the skilled labor necessary to align the fiber to the laser transmitter.

Armiento and his GTE colleagues have pioneered a packaging style called the silicon waferboard, which uses silicon rather than a circuit board as a platform. Passive mechanical alignment features are micromachined onto the waferboard surface so components can be positioned with submicrometer accuracy. For example, optical fibers laid in etched V-grooves are automatically aligned to an array of lasers that is positioned by stops etched into the silicon.

Using this approach, GTE Labs has demonstrated individually addressable four-channel transmitter arrays on silicon waferboards where each fiber operates at 1 Gb/s. The 1.3-μm InGaAsP/InP lasers on the silicon waferboard are spaced only 350 μm apart. The result is a compact module for interconnects that can be incorporated into a computer or telecom switching system.

Other organizations around the world are pursuing their own hybrid IC schemes. IBM has developed an optoelectronic IC technology for short-wavelength interconnects in which microscopic pedestals and solder bumps serve to align arrays of AlGaAs/GaAs lasers with multimode silica optical waveguides. In Europe, Bell Northern Research-Europe, GEC-Marconi, and Siemens are active in this area, as are Fujitsu, Hitachi, and Toshiba in Japan.

Who sold most telecom equipment in 1991*



* In U.S. dollar billions.

a Includes revenues of Teletra and other acquisitions.

b Excludes equipment rental.

c Excludes 40 percent share in GPT.

d Includes STC revenues since March 1991.

e Year-end is March 31.

f Includes Timeplex revenues from October 1991 on.

Source: Dataquest Europe, 1992

[2] When the leading telecommunications equipment suppliers are ranked in order of 1991 revenues, the France-based multinational Alcatel SA is seen to earn about 50 percent more than the U.S.-based AT&T Co., until 1990 the world's top supplier. (At press time, no estimated figures for 1992 were available.)

Data communications

- **ATM Forum established**
- **Gigabit testbeds promote images**
- **More businesses buy into Internet**
- **Low-orbit satellites win a following**

High-speed data highways and wireless data transmission drew much closer to implementation in 1992, though the same could not be said for the integrated-services digital network. Supporters of the asynchronous transfer mode of packet switching—a.k.a. cell relay and cell switching—set up the ATM Forum, which almost at once published ■ key standards specification. Also, the U.S. government's National Research and Education Network (NREN) program made solid progress in the gigabit-per-second realm. And Internet grew apace.

Meanwhile, integrated-services digital network (ISDN) activity was slight until November's promise of a revitalization [''Warming trend with turbulence,'' p. 44]. The narrowband variety will serve homes nationwide, it is suggested, while business may possibly wait for the faster services of broadband ISDN (B-ISDN).

A LA MODE. The transition to ATM for future networking is all but inevitable, said John McQuillan, a consultant in Cambridge, Mass. (ATM stands for asynchronous transfer mode, ■ method of switching data packets of fixed length.) McQuillan believes the changeover will take several years, starting with local-area networks (LANs) this year.

The technology's lure is global, as evidenced by the ATM Forum, which is headquartered in Mountain View, Calif. Organizations from around the world are flocking to join this rapidly growing association; as of October 1992, about 150 belonged, including stock brokerages, government departments, common carriers, vendors, and universities. The Forum's secretariat is Interop Co., in Mountain View, Calif.

Interop is also the secretariat for the Frame Relay Forum and the SMDS Interest Group (SIG). Commercial frame relay offerings have proliferated, overshadowing (at least temporarily) the efforts of the Bellcore-hatched switched multimegabit data service (SMDS).

The Frame Relay Forum has persuaded its 100 vendor members to comply with international standards. Extensions to the standards, called the Local Management Interface (LMI), ensure the interoperability of members' equipment. The technology has spread to Europe, despite ■ reluctance there to abandon the X.25 packet-interface scheme, frame relay's predecessor.

Ray Sarch Contributing Editor

The extent of Europe's interest in frame relay is exemplified in its deployment last June by France Télécom, the government postal, telegraph, and telephone (PTT) agency, on Transpac, the national packet-switched network. But France Télécom called it ■ ''complementary offering'' and warned users that ''frame relay will be less efficient than [X.25] over error-prone links.''

SMDS trials have been ongoing since 1990 among the regional Bell operating companies (RBOCs) and other service providers in the United States. By 1992, many of the companies were filing tariffs, deployments had begun, and the SMDS Interest Group had grown from five to more than 50 members. All indications are that SMDS and frame relay will coexist—at least for ■ time.

UNI SPEC. To revert to the ATM Forum, ■ major accomplishment was its publication last June of the ''ATM User-Network Interface Specification, Version 2.0.'' The ATM UNI spec, as it is known, defines public and private interfaces, specifying ATM user devices and private and public ATM network equipment. As the spec points out, distance is what mostly distinguishes public from private in this context, with the result that the two interface types ''may utilize different physical media.''

The publication consists of individual specifications for physical layer interfaces, for the ATM Layer, and for local management (interim)—all meant to be a guide for ATM vendors and other interested parties. Scheduled to be added by about March is material on Quality of Service (QOS) and Traffic Management. Tests of the interoperability of ATM vendors' products are to include a check for conformance to the UNI Spec as of this year, said Irfan Ali, vice president of ATM Forum. He expects carrier use of ATM in a year's time.

> **HIGHLIGHTS**
>
> **Success:** The ATM Forum was firmly established and issued its ATM User-Network Interface specification.
>
> **Shortfall:** Gigabit testbed progress at some sites was delayed by the late delivery of Sonet-based fiber facilities.
>
> **Notable:** The Internet did well in multicast multimedia tests and broadened its commercial utilization.
>
> **Newsmaker:** Frame relay offerings and usage proliferated to a startling extent.

NUTS AND BOLTS. In a typical ATM application, wide-area networks (WANs) will use the synchronous optical network (Sonet) to provide, ''through a framing structure, the payload envelope necessary for the transport of ATM cells [packets],'' to quote the UNI spec. That is, the transmission system for ATM cells is based on Sonet standards. [Also, see ''B-ISDN and how it works,'' *IEEE Spectrum*, August 1991, p. 39.] As one of its biggest boosters, McQuillan believes that ATM will do away with the distinction between local- and wide-area networks. In other words, distance will no longer be a network-defining factor.

Of like opinion is Roshan L. Sharma, a consultant in Dallas. He said, ''The introduction of economical switches based on ATM technology and the availability of Sonet highways are about to usher in an era of fully integrated digital networks.'' Voice, data, and image will be integrated through the use of ATM switches, he said, but, though ATM testing has already started, he does not expect the era to begin until 1995.

The first generation of these ATM switches exists today, according to Brij Bhushan, head of the Reston Consulting Group, Herndon, Va. Vendors already publicizing their ATM wares include Adaptive, Cabletron Systems, SynOptics Communications, Fujitsu, MPR, NEC, AT&T, NTI, and Ungermann-Bass—all with products on offer or on the way. Digital Link, Sunnyvale, Calif., and Wellfleet Communications, Bedford, Mass., have come up with a jointly developed interface that enables routers to access ATM networks. Not to be outdone, Digital Equipment Corp., based in Maynard, Mass., has announced its multipurpose GIGAswitch platform, one of whose purposes is to accommodate ATM.

Tied in with the ATM activities are the gigabit-per-second testbeds that are sprouting in data communications research facilities, many funded by the Defense Advanced Research Projects Agency (Darpa), Arlington, Va., and the National Science Foundation (NSF), Washington, D.C. Among them are the five testbeds coordinated by the Corporation for National Research Initiatives (CNRI), Reston, Va. Carriers, universities, and industry and government research laboratories are collaborating on this testbed

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research, which will benefit the proposed NREN Internet. The NREN is intended to link research communities in government, industry, and higher education.

A promising NREN application involves distributed computing based on multiple supercomputers and workstations. Another is the real-time processing of composite high-speed data streams, whose reliable management is seen by CNRI as a stiff challenge. A third possible NREN application is for electronic libraries using automated information retrieval programs, such as Knowbots, for queries. A provocative macro view of NREN is CNRI's conjecture that gigabit networks presage a gigantic shift from text- to image-based communications.

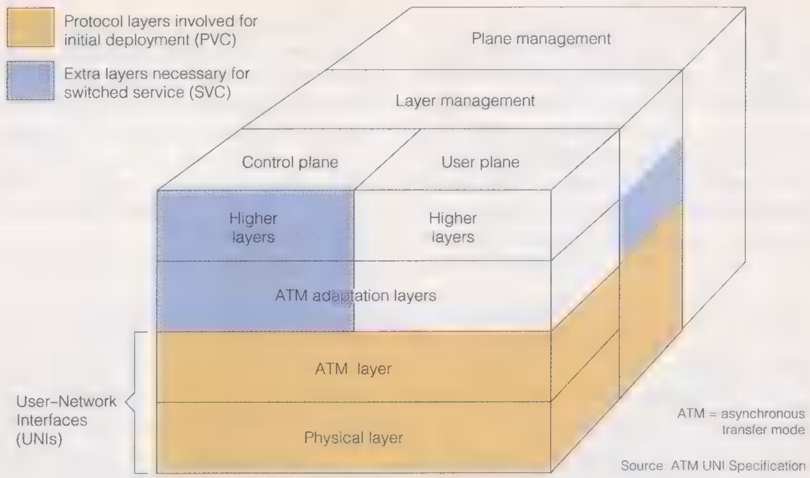
The five CNRI testbeds are at different stages of development, said Richard Binder, a principal scientist at CNRI. One of them, Vistanet, had end-to-end ATM/Sonet facilities installed last summer; data rate is 622 Mb/s. Binder expects that all five testbeds will be up and running by early this year. The others include Aurora and Casa.

David Clark, senior research scientist at the Massachusetts Institute of Technology's Laboratory for Computer Science in Cambridge, Mass., noted a surprising fallout of the testbed activities: they are "some of the first examples of carriers actively working with computer companies toward a common data objective."

FACE-OFF. At Aurora, another of the gigabit testbeds, Bell Communications Research (Bellcore), Morristown, N.J., and IBM Corp. are comparing ATM switches. David Sincoskie, executive director of Bellcore's computer networking research, is supplying Aurora with the Sunshine experimental prototype switch. Inder Gopal, IBM's manager of broadband networks at the Thomas J. Watson Research Center, Yorktown Heights, N.Y., is supplying Aurora with the Planet PTM (packet transfer mode) switch. The length of the ATM cell, or packet, is fixed at 53 bytes, of which five are reserved for the header; PTM's packet varies in length and "has no intrinsic limit," Gopal said. The upper operational limit last fall was "about 2 kilobytes." He claimed that PTM can also handle fixed-length packets and can mix the two types.

Sincoskie said that ATM is here to stay. He granted that Planet has some ATM capabilities, but labeled it "a high-performance multiprotocol router." PTM is not yet under consideration as a standard, he added, but is viable for the long term. Sincoskie sees Planet aimed at private networks; ATM, at the phone companies' central offices. He believes that the two, while not fully compatible now, will coexist and compete in the National Science Foundation Network (NSFNet) market for internet protocol networks.

Another gigabit testbed, Casa, was scheduled to complete its first phase, interconnecting the Jet Propulsion Laboratory (JPL) and the California Institute of Technology,



A protocol is an agreed-upon set of rules for communications. The one that the ATM Forum's User-Network Interface (UNI) uses is adapted from the broadband integrated-services digital network (B-ISDN) protocol. The reference model is represented by a cube of planes and layers, symbolizing the multiple interactions of the adjacent layers. The protocol layers involved at UNIs may include any higher-layer protocols required for UNI management.

both in Pasadena, Calif., by the end of 1992. Links with the San Diego Supercomputer Center and the Los Alamos National Laboratory in New Mexico are expected early this year. Richard Mizer, the Casa project manager for Pacific Bell (PacBell), San Ramon, Calif., said that Casa is, in part, a technology test of Sonet as a scheme for gigabit data transport, and its implementation will be the first use of such a technology by PacBell.

A key Casa element is the high-performance parallel interface (Hippi) Sonet gateway supplied by the Los Alamos National Laboratory. This gateway will carry Hippi-based data over Casa's long-distance Sonet links.

Northern Telecom Ltd., Mississauga, Ont., is supplying its S/DMS TransportNode as a backbone device. (The company says that the initials stand for Sonet digital multiplex system.) The S/DMS accepts up to 16 optical Sonet user-interface inputs of 155 Mb/s (Sonet OC-3), converts them to electronic signals, and multiplexes them directly to the OC-48 rate of 2.4 Gb/s—a first. And this highlights another Casa first: an end-user interface that passes Hippi signals over eight parallel OC-3 channels.

BAGNET. PacBell shows up in another testbed project, the Bay Area Gigabit Network (nicknamed Bagnet) in California. Although still in planning, it could become a sixth gigabit testbed, said PacBell executive director Yuet Lee, one of its prime movers. He added that about 15 organizations wish to share in Bagnet's development, with the aim of becoming experimental users. The planned research capabilities include multicasting (many-to-many) videoconferences and storing seminars, all operating interactively. The network will be broadband and use ATM technology.

A testbed called Project Zeus, but unabashedly aimed at the commercial market, has been in operation at Washington University in St. Louis, Mo., since 1990. Under the direction of Jonathan S. Turner, chairman of the university's computer science department, the working model has grown into a 30-km broadband ATM network with four nodes, each capable of 1.6 Gb/s and with up to 16 ports. The Zeus campus network will provide an access rate of 155 Mb/s by mid-1993, with 600 Mb/s later. Interfacing with NSFnet is also planned.

Turner's ATM switch avoids the fixed-path routing of other commercial switches. As in other banyan switches, each cell finds its own path through the switching system. Turner's switch buffers at each stage, which could result in a more even load distribution, a reduced internal bandwidth demand, and more efficient multicasting. In fact, Washington University's Applied Research Laboratories dubs it the "first functional prototype ATM switch with multicast architecture."

After lengthy negotiations, Turner has interested two commercial vendors, both members of the ATM Forum. SynOptics Communications Inc. of Santa Clara, Calif., is one. It recently announced that it was developing a set of six chips for ATM switching products based on Turner's architecture. The resulting networks will handle voice, data, and video communications at a hundred times today's network speeds, said Ronald Schmidt, SynOptics' cofounder and chief technology officer. Turner asserts that his technology provides at least 155-Mb/s bandwidth to each switch-linked network port.

The other vendor involved in Turner's endeavors since last July is Ascom Timeplex, Woodcliff Lake, N.J., whose Swiss parent is Ascom Companies. Director of business development Kenneth S. Hoyt said that the contract with Washington University calls for joint research in ATM chip sets, signaling, network management, and applications.

Meanwhile, Ascom Tech Ltd., the corporate research division of Ascom Companies, is leading the development of an ATM testbed network in Basel, Switzerland, as

part of the RACE program. The goal of RACE (which stands for research and development in advanced communications technologies in Europe) is to develop integrated broadband communications (IBC) over a public broadband network. The Belgian broadband ISDN trial, a larger RACE-supported effort, is being led by Alcatel NV. Present or planned RACE activities include: evolving signaling to accommodate multipoint, multimedia communications; exploring code-division multiple access (CDMA); developing a passive optical network; determining the benefits of teleshopping applications, including electronic funds transfer on an ATM B-ISDN network; and defining the architecture of mobile networks, paving the way for a universal mobile telecommunications system (UMTS).

Back in the "slow lane," the Internet is picking up speed. About 10 000 networks and more than a million computers are now connected, with the computer population doubling every seven months, according to Insight Research Corp., Livingston, N.J. Director Robert Rosenberg said, "TCP/IP has become the dominant mode of internetwork communications. The Internet has become the common tongue of data networking."

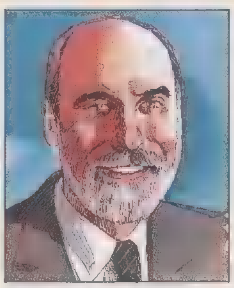
EXPERT OPINION: Warming trend with turbulence in the lower layers

VINTON G. CERF

After reviewing the 1991 and 1992 technology reports in *IEEE Spectrum*, one is tempted to dismiss last year as yet another 12 months of rapid change in data communications technology and policy. But what with movies invading the phone lines and phone calls invading cable, it has been far from boring.

A milestone for the integrated-services digital network (ISDN) was the Golden Splice set for Nov. 16, 1992. On that day, most major local and interexchange carriers were to have set up and operated the first phase of a national ISDN "roll-out"—not just a demonstration, but a system that is to remain a tariffed offering in a score of U.S. cities. More ISDN-capable equipment for customer premises was revealed, including cards for PCs and workstations. So perhaps this will be the year in which ISDN plays a big part in providing homes especially with faster access to wide-area data networks, both private and public.

Frame relay, too, has surely set some records for speed of commercial deployment. It seems to have temporarily upstaged switched multimegabit data service (SMDS), though this situation may change as cell-switching systems, together with synchronous optical network (Sonet) transmission systems, are introduced. A weakness of frame relay is its permanent virtual circuit (PVC) orientation, at least as fielded. PVC is adequate for local-area networks (LANs) within a company, but dynamic switching is needed to send data between arbitrary organizations.



'ATM switches may well find their way into local- and wide-area networks this year, at least experimentally.'

As for switching technologies, asynchronous transfer mode (ATM) switches may well find their way into local- and wide-area networks this year, at least experimentally. Several ATM products have made it to market. Some even aim at LAN applications supporting 155-Mb/s access, which makes them more than competitive with fiber distributed data interface (FDDI) rings. The switches will certainly play a role alongside high-performance parallel interface (Hippi) crossbar and IBM Planet gigabit switches in the gigabit-per-second testbed efforts sponsored by the Defense Advanced Research Projects Agency and the National Science Foundation. The ATM Forum's founding in 1992, moreover, signals serious product development interest in the telecommunications and computing business sectors.

The boundary between telephone and cable TV services blurred. A surprise on the policy front was the Federal Communications Commission's decision to permit local exchange carriers into the video dial-tone business. The feasibility of pay-per-view movies over copper local loops has been demonstrated at Bellcore, which used asynchronous digital subscriber loop (ADSL) techniques to support one-way 1.544 Mb/s to the subscriber above a two-way voice line. Combined with a modified TV remote controller for signaling to the head end, subscribers can fast-forward, freeze-frame, and reverse, as well as select which films to watch. Alternatively, high-speed digital subscriber loop (HDSL) technology could deliver full-duplex 768-kb/s service on a wire pair and twice that on two wire pairs. With such an arrangement, compressed video could, for example, be transmitted from, as well as to, residences.

Conversely, cable carriers began serious competition for local exchange service. Phone service over coaxial TV cable was demonstrated over a decade ago, but only now is the technical, economic, and political climate receptive to commercial offerings. Digital cellular radio meanwhile seems destined for a key role in the personal communications infrastructure.

The rapidly growing Internet system conjures up a different perspective of possible future telecommunications services. Packet voice and video multicasts were carried out on the Internet to more than 200 sites in 10 countries during 1992. Meetings of the Internet Engineering Task Force (IETF) are linked to the Internet by workstations with video and audio hardware that packetize and compress real-time video and voice. The latter technology is still in its early stages, but demand is brisk, being made brisker by the falling costs of video codecs and inclusion of sound and video capabilities in PCs as well as workstations.

Internet activities were widespread. Internet electronic mail was enhanced with multimedia and cryptographic privacy/signature capabilities during 1992. A cornucopia of Internet information-searching services spilled forth, including the Wide Area Information Service (WAIS), Archie (file service), gopher (general text file search system), World Wide Web (hypertext), and various kinds of Knowbot programs. The nonprofit, professional Internet Society was formed, and the Internet Architecture Board, Internet Research Task Force, and IETF were integrated into it. Providers of Internet services either emerged or expanded as commercial information services were brought up on the system, so that speculation persisted about how to manage intellectual property in networked environments.

Even the lowly copper subscriber loop, without HDSL or ADSL modification, may undergo a sea change shortly. Using touchtone phones, Bellcore (in New Jersey) has been demonstrating a two-way signaling scheme that emulates many of the ISDN D-channel functions. Combined with suitably equipped palmtop computers, simple user interfaces to complex services, like call set-up, dialing, forwarding, and answering, can be created. As a step in the ISDN direction before ISDN is available, it may allow PC and workstation vendors to offer computer-managed phone, fax, and e-mail services over unmodified analog phone circuits, for a while.

Talk about Personal Communications Numbers (telephone numbers that move with you as you travel) is cheap, but there is a lot of work to do before this will be satisfactory. Callers used to reaching parties by local exchange may be surprised at the bill when the called party happens to be in Brisbane, Australia. Presumably, callers will be warned before the call is completed, in case they prefer a different means of communicating.

Vinton G. Cerf (F) helped develop the Arpanet host protocols while at the University of California at Los Angeles from 1967 to 1972. At Stanford University in California (1972–76), he led a research project that developed the transmission control protocol/Internet protocol (TCP/IP) suite. He has been vice president of the Corporation for National Research Initiatives, Reston, Va., since 1986, besides being current president of the Internet Society.

The transmission control protocol/Internet protocol (TCP/IP) is operational in far more networks than its competitors are, Rosenberg said, and has about five million end-users in 40 countries. The user count is growing at 15–20 percent yearly. Of all registered networks and subnetworks, nearly 60 percent are commercial organizations, and that proportion should reach 90 percent by 1994.

The commercializing of Internet is the driving interest of the Commercial Internet Exchange (CIX) Association Inc., Falls Church, Va. Members of CIX are U.S. and European organizations that offer the public TCP/IP or OSI (open systems interconnection) data internetworking services in multiple geographic locations.

During 1992, voice and video multicast tests were held over the Internet by the Internet Engineering Task Force (IETF). Audio from several sessions at its March meeting in San Diego, Calif., was multicast to 20 sites on three continents. The remote participants could engage in discussions with the San Diego speakers. The audio data rate was 64-kb/s pulse-code modulation (PCM) at each of 20 Sun Sparcstations. The sound ranged from "intelligible" to "very clear." It was felt that more work was needed in several areas, including better real-time measurement tools and ubiquitous multicast routing support.

At the July IETF meeting in Boston, both live audio and video were multicast to participants in 10 countries. The audio transmission was received by 170 workstations. Video was transmitted at two to six frames per second to 75 of the workstations and displayed after software decompression.

However, resource management would have to be implemented in the Internet before real-time traffic could occur on any significant scale, noted Stephen Casner, project leader at the University of Southern California's Information Sciences Institute, Marina Del Rey, Calif. "To reach the many more places that would like to participate," he said, "we'd like to expand the IETF multicast topology to form a semipermanent virtual Multicast Backbone (MBONE) to serve as a testbed for continued experimentation."

Other Internet activities include IETF work to reconcile ISO and simple network management protocol (SNMP) standards versions. Also, work is being done on the address depletion problem and on extending Internet addresses to accommodate more hosts, networks, and users.

RED FLAG. CNRI vice president Vinton G. Cerf noted that the Internet workstations are increasingly being equipped with sound and video boards. He warned that the Internet is not presently configured to support much real-time demand and, given its current growth rate, could very well become overloaded later this year.

One IETF working group is investigating a quite different application for the Internet: connecting to mobile computers. In the near term, the group is chartered to develop protocols for a host "roaming" among assorted subnetworks and media. Examples are LANs, dial-up links, and wireless communications channels. One requirement, according to Stephen Deering, member of the technical staff at Xerox Palo Alto Research Center's Computer Science Laboratory, is that the proposed schemes allow mobile hosts to operate with existing Internet systems. Deering is the creator of multicasting in Internet.

Longer-term projects may include mobile clusters of devices, such as the collection of hosts and subnets within a large vehicle, like a ship or spacecraft. The working group's 1992 goals included an Internet draft documenting the mobile host's protocol. In 1993, the group plans to propose a standard for a mobile host protocol to the Internet Engineering Task Force Steering Group (IESG).

IN ORBIT. The Internet-to-mobile-computer working group has some competition. Last July, Motorola Inc., Schaumburg, Ill., introduced what it termed the first nationwide wireless electronic-mail and data service. Called Embarc for electronic mail broadcast to a roaming computer, the service is said to deliver wireless electronic information to thousands of computer users simultaneously. The receiving devices can be laptop, notebook, and palmtop computers, and messages are relayed to them from a satellite's downlink station. Initial coverage was for 44 states. A delivery in 15 minutes of 100 characters costs 63 cents after a one-time basic-package charge of $395.

One 1992 event is scheduled to bear fruit in 1997—with skeptics predicting that the fruit will die on the vine. This is Motorola's grandiose Iridium project. The idea arose when the international authorities granted the necessary radio frequencies for the operation of low-earth-orbit satellite systems, with a view to the creation of networks linking wireless phones and portable computers. Iridium's design calls for 66 polar-orbiting, 800-km-altitude satellites (scaled back from the original 77, which is the number of electrons in the iridium atom). Besides worldwide phone service with a special handset, Iridium is supposed to offer facsimile and paging services.

Cost estimates for Iridium have reached $3.1 billion, of which Motorola's share is about $150 million. The balance would come from outside investors. Skeptics cite negative investment advisories and the satellites' five-year life expectancy (geostationary satellites last 15 years) as among the reasons for their doubts.

Despite the skeptics, four other companies are proposing to offer services based on the low-orbiting satellites. Two are start-ups—Ellipsat Corp. in Washington, D.C., and Constellation Communications Inc., Herndon, Va.—and a combined venture between Loral Corp., New York City, and Qualcomm Inc., San Diego, Calif. Their simpler and much less costly offerings would use the low-orbiting satellites to bounce signals between portable devices and earth stations run by phone companies.

GETTING PERSONAL. Last May, Apple Computer Inc., Cupertino, Calif., announced the availability in early 1993 of Personal Digital Assistants using its Newton technology. In development for more than four years, this technology uses reduced-instruction-set computing (RISC) processors. The products based on Newton will "use digital technology to bridge the gap between personal computers and consumer electronics," Apple said.

The first Newton products will be portable electronic notepads, Apple said. With their built-in wired and wireless communications capabilities, their users could fax a letter, check electronic-mail messages, or link up with a satellite news service.

Besides licensing Newton technology to Sharp Corp. of Japan, Apple announced support for Newton by Motorola, Pacific Bell, Random House, SkyTel, and Traveling Software. No pricing or other communications details were available.

THE COMBINATION. Last year, multimedia—the interactive employment of audio, video, and data—inched more to the fore. In March, Pacific Bell, IBM, and Northern Telecom reported the start of a long-term effort to develop broadband communications for multimedia applications. Insight Research reported that IBM is looking at multimedia for telecommuting and teleconferencing uses. Meanwhile, PacBell and Northern Telecom will be assessing how well their systems might handle network-based services for broadband multimedia.

According to the Insight Research report, vendors of the stature of Digital Equipment, IBM, Lotus, and Oracle, are adding multimedia images to documents and databases. The result will be extensive distribution of multimedia images throughout departments and enterprises over local- and wide-area networks. Typical applications are in education for distributing courseware throughout a school or campus via a LAN, interactive sales presentations or conferences, and the distribution of image files from a central library to either health care or manufacturing worksites.

Internetworking—the connection of multiple networks—enables workers in different locations to collaborate on projects, either in real time or at their convenience. Multimedia groupware ranges from Lotus Notes, to Oracle and Informix databases and the dynamic object-sharing capabilities recently added to Microsoft Windows and Apple's Macintosh System 7.

One other multimedia entry involves a LAN from Zenith Electronics Corp., Glenview, Ill. The scheme uses an existing cable-TV network as the backbone for LAN data transmissions, which coexist on it with the other services.

Solid state

- **Breaking the 200-MHz barrier**
- **Multimedia goes consumer**
- **Notebook PCs drive 3-V technology**
- **DRAMs get second wind—again**

Semiconductors fared about as well, or ill, as the general market in this year of a global recession. Industry growth rates were down 6–7 percent between 1991 and 1992, versus the rise of 8 percent during the same period in 1990–91.

Individual markets varied, however. Usually the United States, Europe, and Japan track each other in semiconductor sales, according to Doug Andrey, manager of statistical programs at the Semiconductor Industry Association, San Jose, Calif. Last year, though, in large part because the three regions have different focuses, U.S. sales were up 15 percent, European sales were relatively flat, and Japanese sales dropped approximately 10 percent.

"Japan is suffering from a glut of consumer electronics: everybody who wants a VCR has one," Andrey told *IEEE Spectrum*. "The U.S. semiconductor industry is much more focused on the computer and in particular the PC market, where demand is still on the upswing. Europe, while primarily a consumer electronics market, is still expanding into the former Soviet Bloc and is holding its own." Andrey noted that the countries on the Asia-Pacific Rim have grown over 20 percent in each of the last four years and are close to Europe's semiconductor sales volume.

But while semiconductor sales as a whole cooled off, the battle to supply the IBM PC market heated up. Dataquest Inc., the San Jose, Calif.-based market research firm, estimates that the market in Intel 80X86-compatible microprocessors is worth as much as US $3.7 billion, and in hopes of cashing in, a number of other companies released processors compatible with the 80386 and 80486 this year.

Not everyone sees a gold mine in this market, though. For instance, Chips & Technologies Inc., San Jose, Calif., decided to abandon attempts to develop products beyond the 80386 for the general market. Instead, it will concentrate on more specialized products for portable computers.

Meanwhile, Intel Corp., Santa Clara, Calif., continued to release new products one step ahead of everyone else. Last year saw the debut of its OverDrive processors, which are variations of the 80486DX that operate internally at twice the external clock speed; they allow designers to almost double the speed of computationally intensive programs without modifying their designs. Early this year, Intel is expected to release the successor to its 80486DX, the Pentium microprocessor. Moreover, with the gathering sales momentum of its 80486, a product in which the company has a distinct market share advantage, Intel has begun aggressively pricing its 80386 line in an attack on competitor's profit margins. (This price fight has been behind the steep decline in the price of IBM PC compatibles over the last year.)

IBM Corp. is one of the world's largest producers of semiconductors, as well as computers. This production has been captive, however, with the equivalent of an estimated $8 billion worth consumed internally by IBM products. IBM Technology Products, Somers, N.Y., Big Blue's semiconductor branch, announced that in 1993 it will enter the merchant IC market with a wide range of products previously restricted to IBM equipment. The plan is to focus on ICs for computers, including dynamic RAMs and memory cards, complementary MOS (CMOS) and bipolar CMOS application-specific ICs, BiCMOS (ASICs), and video products.

Sematech Inc., the Austin, Texas–based research consortium, reports that it is advancing steadily toward its goal of boosting U.S. expertise in semiconductor manufacturing. To quote its chief executive officer, William J. Spencer: "Five years ago Sematech set out to demonstrate 0.35-μm line width manufacturing technology on 200-mm wafers, a goal we will attain on time and on budget. As a result of the improvements in U.S.-made equipment, American semiconductor equipment suppliers have retaken the lead in market share." Sematech is aiming much of its research at software modeling of semiconductor manufacturing, an area in which it feels that the United States has and can continue to maintain a leadership position.

In fundamental semiconductor research, several advances were reported this past year. Fujitsu Ltd., Tokyo, claimed that it had made a breakthrough in the development of high-electron-mobility transistors (HEMTs), used in telecommunications and switching applications. Its HEMT asynchronous transfer mode switch, which could be a key element in implementing a broadband integrated-services digital network, achieved a throughput of 9.6 Gb/s. Researchers at IBM Corp., Yorktown Heights, N.Y., announced that they had achieved a new speed record for a BiCMOS process, integrating 60-GHz bipolar devices with 0.25-μm CMOS devices. IBM also announced that it had fabricated 700-by-150-nm n-channel MOSFETs, 20 times smaller in area than previous transistors, which would be the building blocks for 4G-bit DRAMs.

CRITICAL MASS. The trickle of low-voltage devices seen last year has since turned into a torrent, driven by the notebook/palmtop computer. Consumers have two basic complaints about the portable machines: they are too heavy, and battery life often falls far short of the all-day operation that would make them practical. Running these systems at 3.3 V would help on both counts. By cutting power consumption by up to 63 percent, it would extend battery life and even allow the designer to jettison some of the heavy battery cells.

Accordingly, almost every major manufacturer of digital ICs has released devices running at 3.3 V or less ["ICs going on a 3-V diet," *Spectrum*, May 1992, pp. 22–25]. Devices available in low-voltage versions include dynamic RAM, flash memory, gate arrays, and digital signal processors.

The supply of low-voltage logic has now reached "critical mass," smoothing the way to its widespread adoption. "A year or so ago it was nearly impossible to find enough 3.3-V parts to build a complete design," John Williams, technical marketing engineer at Intel's operation in Chandler, Ariz., told *Spectrum*. "It is still a challenge, but you can now find enough 3-V logic to complete some fairly sophisticated projects." During a recent design project, Williams surveyed the industry on the availability of 3.3-V devices and was able to compile a list that was more than

HIGHLIGHTS

Success: DEC processor breaks the 200-MHz barrier.

Shortfall: Annual semiconductor industry growth falls 6 percent between 1991 and 1992.

Notable: Notebook and high-speed computer applications push 3.3-V logic.

Newsmaker: Sematech research consortium reaches its first five-year goal by producing wafers 200 mm in diameter and with 0.35-μm line width.

Kevin Self Contributing Editor

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EXPERT OPINION: Preparing for the nomadic age

TSUGIO MAKIMOTO

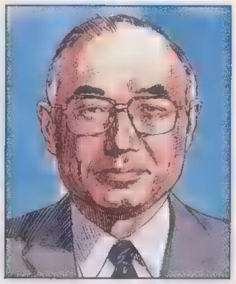
Advances in PCs now allow anyone to operate a computer wherever he or she can turn it on, at a level of computing power reserved to users of large computers several years ago. In addition, improvements in communications between computers mean that individuals can now receive more information over longer distances in shorter periods of time. Continuing technical innovations in the coming decade will integrate more computer and wireless communication capability into portable equipment. This will usher in the age of nomadic computing, computing anywhere and communicating everywhere, as described by George H. Heilmeier of Bellcore at the 1992 IEEE International Solid-State Circuits Conference (ISSCC).

The important trends in semiconductor technology that led us to this new age are higher speed, lower power, and more programmability. The first two put increased functionality on a single chip while simultaneously reducing power consumption. Programmability, crucial for highly integrated large-scale ICs, helps to maintain the balance between a system designer's customization requirements and the production efficiency required by the IC manufacturer. Much of the progress in these areas has been made only in the last year or so.

The two most striking advances in high-speed operation last year were made in reduced-instruction-set computing (RISC) and memory architectures. Advanced process technology and elaborate circuit design, especially in clock drivers, have pushed the operating frequency of RISC microprocessors to 200 MHz. Many of these techniques were shown at ISSC last year.

Superscalar architecture and superpipelining, in addition to increasing operating frequency, further add to the millions of instructions executed per second. An experimental chip developed by Tokyo's Hitachi Ltd. has demonstrated the potential of 1000 million instructions per second (MIPS) through the use of 0.3-μm bipolar CMOS technology.

Increases in microprocessor speed have created their own set of problems, however. A speed gap has arisen between the processor and the main memory subsystem, where the processor can demand and process data faster than the memory subsystem can supply it. A cache memory utilizing high-speed static RAM can fill the gap, but at great expense. A cost-effective solution may be new dynamic RAMs (DRAMs), which can directly communicate with high-speed microprocessors. Other design innovations like special clocking and small I/O signaling enable bandwidths of up to 500 megabytes per second using current mass-production technology.



'Superscalar architecture and superpipelining. . . further add to the millions of instructions executed per second.'

Together with high-speed computing, high-speed communication will be a key factor in the nomadic age. Many high-frequency devices are under development to commercialize 1–10-Gb/s data rates in the near future. Although gallium arsenide technology has been dominant in this field because of its high cut-off frequency, the economics of silicon technology still make it attractive for commercial use. Research is demonstrating the feasibility of silicon bipolar transistors as well as AlGaAs/GaAs heterojunction transistors for communication applications.

The original impetus to lower operating voltages was the need to improve the reliability of fine-geometry devices such as DRAMs. The conversion to 3.3 V and lower has proceeded much faster than predicted, spurred on by the trend to transportable computing. The portable equipment of the nomadic age will have to consume less power, and low power and high speed can only be achieved simultaneously by reducing the operating voltage. In addition, lower voltages reduce noise and electromagnetic interference (EMI), factors becoming increasingly important as the computing devices move off the desktop into harsher environs. One cannot build a low-power computer with ICs alone, however, and further work will have to be done to create components such as batteries and peripherals that will operate at the lower voltages.

Application-specific ICs (ASICs) allow designers to combine many complex but customized functions on a single IC, reducing the chip count and shrinking the size of the finished product. The tradeoff has been increased cost and longer design cycles. The implementation of field programmability on a highly integrated semiconductor device minimizes this problem in today's ASICs. Designers can quickly debug, test, and reprogram these devices, eliminating the cost and time associated with producing fixed-pattern versions of the same device. In addition to improvements in programming technologies, many new architectures for field-programmable devices have been invented since the PROM was introduced in the market as the first programmable device. Architectures such as field-programmable gate arrays (FPGAs) and flash memory are gaining wide popularity in portable equipment as a versatile compromise between development speed and cost.

Tsugio Makimoto (SM) serves on the board of directors of Hitachi Ltd. and is the general manager of Hitachi's Semiconductor and IC Division. His current responsibilities include all semiconductor operations, including microprocessors, memories, application-specific ICs, linear ICs, and digital large-scale integration.

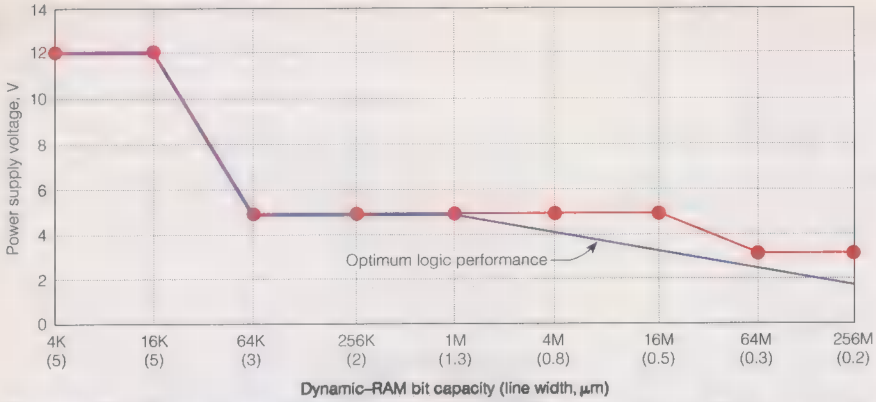
15 pages long [To probe further, p. 82].

Still, the growing speed with which the industry is moving toward 3.3-V logic is both too slow and too fast for many in the industry. Designers are finding that many devices are still only available in 5-V logic and they must use voltage-level translators or devices specifically designed to interface with both voltages. For IC vendors, the transition is moving quickly enough that they are not willing to put the effort into designing mixed-voltage parts needed in the interim. As the move to 3.3-V is not expected to be completed until early next year, designers will meanwhile be called upon to devise work-arounds for mixed-voltage systems.

Many of the 3.3-V introductions are 5-V devices recharacterized at lower voltages. The low-voltage versions typically run slower, however, because the drain-source current is reduced as the square of the gate-source voltage. Internal capacitors require longer to charge at the lower current, which then must run at a reduced frequency. Williams notes that derated parts "can be very useful in battery-powered systems. Because they can run at both 3.3 V and 5 V, designers can avoid using voltage regulators in their systems."

The trend toward lower voltages does not stop at 3.3 V. Atmel Corp., San Jose, Calif., is already offering 1.8-V devices—its AT93C46 family of serial electrically erasable programmable ROMs. As dynamic RAMs (DRAMs) continue to shrink, they will drag operating voltages down with them. "DRAM designers are already looking beyond 3.3 V," observed Betty Prince, manager, new products, MOS memory worldwide marketing for Texas Instruments Inc., Houston, Texas. "The 64M-bit DRAM, the next jump in DRAM sizing, is the technology driver for an inherently 2.5-V process."

NEW MEMORIES. Designers of battery-powered systems are especially hungry for 3.3-V memory devices, since memory uses a lot of power in portable computers. Prince noted that many memory chip designers mean to perfect their 16M-bit fabrication process before redesigning current 4M-bit dice for 3.3-V operation. The reason is that the finer geometries required by 16M-bit technology necessitate the use of a lower voltage, approximately 3.3 V. Prince expects this leapfrogging to finish by approximately 1994 as the industry completes its conversion to 3.3 V.



Dynamic-RAM operating voltages have been driven by the need to standardize power supply levels between memory and logic and by device reliability requirements. Denser devices require ever lower voltages, so today's need to standardize at the 3.3-V level has caused the present generation of DRAMs to lag behind the optimal operating voltages. There is some disagreement among experts as to the ideal values, which may diverge even more than shown.

Memory system designers have found it difficult to keep up with the runaway processor speeds, and architectures were unveiled this year to break the memory bottleneck. The Rambus Channel, developed by Rambus Inc., Mountain View, Calif., is an interface specification for specially designed DRAM that can support up to 500 megabytes per second using a synchronous, block-oriented protocol. The Rambus DRAM (RDRAM) is the heart of the Rambus system, transferring 9 bits every 2 ns. Data can be stored in its sense amplifier latches, in effect creating a high-speed cache. The RDRAM is packaged in a vertical surface-mounted package (VSMP), and the die is laid out so that the bonding wires are a uniform, minimum length. Devices must access the Rambus Channel through a Rambus Interface, either on the chip itself or through a bridge device embedded in an ASIC. RDRAMs storing 4M bits will be available in early 1993 from a variety of manufacturers, with 16M-bit versions due later in the year.

In another architectural approach last year, Mitsubishi Electronics America Inc., Sunnyvale, Calif., introduced its cached DRAM (CDRAM)—in other words, a DRAM that incorporates a cache subsystem. The cache has hit and miss access times of 10 and 70 ns, respectively. The use of a write-back cache maintains coherency with main memory. Ramtron, Colorado Springs, Colo., announced an Enhanced DRAM (EDRAM), which incorporates an internal write-through cache to achieve a 15-ns cycle time for cache hits and 35 ns for misses. Synchronous DRAMs (SDRAMs), under development by a variety of manufacturers, look to marry the speed of the synchronous static RAM to the cost benefits of DRAM. The SDRAM's internal cycles are tied to the system clock so that the processor knows exactly when it can retrieve the data from the SDRAM. Until then, the processor can execute other tasks, eliminating the delay associated with a conventional DRAM's access time.

In the analog and mixed-signal field, the big news was the movement of multimedia into the consumer market. Multimedia enables PCs (although the technology is not limited to computers) to transmit and manipulate both audio and moving video data. The rates at which audio and video data must be transferred for multimedia exceed the bandwidth of most communication links. Dedicated multimedia processors, usually digital signal processors, are required to compress and decompress the data between devices so that the system processor is not unduly burdened.

The assortment of products coming to market reflects a greater emphasis on video/audio decoders, as decompression is much less work than compression, and in most consumer applications, such as PC multimedia, playback is more important than recording. The PC is seen by vendors as the key to moving multimedia into the mass market. Most of the products introduced were designed to interface directly with computer buses or the microprocessor, simplifying the task of designing them into standard products already available.

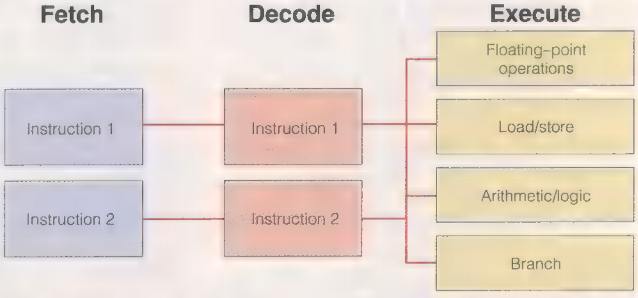
The machine's importance was demonstrated when Intel decided this year to shift resources away from its high-end V3 digital video interface (DVI) multimedia chip and directed them toward its lower-end i750 chip set, designed for PC-based products. "PCs have become powerful enough to handle the video and audio processing that multimedia requires, and we see a tremendous potential as it spreads into business and entertainment applications," Rick Stauffer, marketing manager of Intel's multimedia/supercomputing components group, told *Spectrum*.

Moreover, Texas Instruments' Dallas operation launched a dedicated multimedia processor last year. The TMS320M500 Mwave digital signal processor is a 16-bit, 17-million-instruction-per-second (MIPS) fixed-point core device that supports both hardware and software manipulation of audio and video. It interfaces directly with IBM PC buses to gain access to the host processor, system memory, and a number of peripherals. The processor can reallocate internal resources dynamically, and can support multiple concurrent tasks. For example, it can simultaneously decompress true-color images conforming to the Joint Photographic Experts Group format, decode sub-band coded audio, and time-scale audio data, all while implementing a 2400-baud modem.

The need to interface analog devices with multimedia processors has spurred the creation of several companion products by, for instance, Analog Devices and C-Cube Microsystems. The AD1848 and AD1849 codecs (coder/decoder) from Analog Devices Inc., Norwood, Mass., were developed in an alliance with Compaq Computer and Microsoft. They are single-chip supports of business and multimedia audio for use in PCs and workstations.

C-Cube Microsystems, Milpitas, Calif., introduced its CL450 data decoder last year, designed in support of the Motion Picture Experts Group's standard for full-motion, color-video compression and decompression. The decoder is targeted at the fledgling compact-disc–interactive (CD-I) market, applied everywhere from PCs to Karaoke sing-along machines, and was jointly developed with Philips Electronics NV of the Netherlands, creator of the CD-I standard. The device can compress full-motion color video at the rate of 30 frames per second, generating decoded NTSC or PAL video signals. The device has an on-board memory controller to manage up to 4M bits of local DRAM.

NEW DOGS, OLD TRICKS. Last year's crop of high-speed processors used tricks employed for years by supercomputer designers. Despite silicon's intrinsic speed limits, designers are still finding new ways to squeeze more throughput out of silicon microprocessors. The high-speed chips introduced this year were all designed for and operate



In this superscalar design, instructions are fetched in pairs by the microprocessor, whereupon the decoder determines if the two can be executed simultaneously. Instructions that use the same execution units or depend on each other's results cannot be completed in the same cycle, and for them the processor switches to a sequential mode.

at 3.3 V, so that they reduce transistor switching times and generate less heat, a real problem in high-frequency devices. As designs became more complex, designers turned to reduced-instruction-set computing (RISC) architectures, which execute simple instructions in a single clock cycle. The fastest processors introduced this year are further enhanced by the inclusion of superscalar design techniques, which allow the processor to execute more than one instruction in a single cycle. The use of other techniques like scoreboarding, employed for years in large, multiprocessor supercomputers, are now finding their way into single-processor systems.

The combination of superscalar architecture and high operating frequency is the signature of today's high-speed processors. "The battle between the 'ultraviolet' clock [optimizing computational power through faster clock speed] and the superscalar [executing more instructions per cycle] camps seems to have become a dead issue," said Patrick Bosshart, TI Fellow at Texas Instruments, Dallas, and chair of the Microprocessor Session at 1992's IEEE International Solid-State Circuits Conference. "The processors introduced this year have proved that it isn't an either-or proposition. High-performance processors are going to have to include both."

The DECchip 21064, also known as Alpha, from Digital Equipment Corp., based in Maynard, Mass., is the speedster of this year's entries. Currently operating at 150 MHz, DECchip 21064 was designed for a 200-MHz clock rate and is expected to benchmark at over 150 SPECmarks and a peak speed of 400 MIPS. Detailed attention was paid to the routing of the clock lines, virtually eliminating clock skew so as to support a 6.6-ns cycle time. Alpha AXP was planned as a true 64-bit architecture from the start, sidestepping the problems and delays needed to support compatibility with existing 32-bit systems and byte/word operations. A 0.75-μm CMOS process crams 1.68 million transistors into a 431-pin-grid array, fitted with a finned heat sink to dissipate the 23 W consumed by all those transistors.

Intel has begun releasing information about the Pentium microprocessor, the 80486's successor, now expected in the first quarter of 1993. Fabricated with a 0.8-μm bipolar CMOS process, it will contain over three million transistors. The superscalar design will incorporate a five-stage dual pipeline: instructions are fetched and decoded in parallel, then loaded into each of the pipelines for execution.

Pentium has been measured at over 100 MIPS. No other performance numbers have been released, but it is expected to exhibit four to 10 times the floating-point performance of an Intel 80486DX operating at 33 MHz. The design will incorporate elements of RISC architecture, although many purists classify it as a complex-instruction-set computer (CISC) on the grounds that it can execute the 80X86 instruction set.

Two companies are battling for the high ground in the market for Scalar Processor Architecture (Sparc) devices. These processors form the computational core of workstations based on Sun Microsystems Inc.'s Sparcstation. Texas Instruments, Houston, has started production of its TMS390Z50 SuperSparc chip. Code-named Viking, the project is a joint development of Texas Instruments and Sun Microsystems Computer Corp. The superscalar, single-chip architecture employs a 0.8-μm BiCMOS process with three levels of metallization. It has clocked in at 64.7 SPEC'92 SPECfp points (a measure of floating-point performance) in a 40-MHz Sparcstation 10. An optional companion external cache controller for SuperSparc, the TMS390Z55, has on-board cache tags that support up to 1M byte of cache SRAM.

SuperSparc's competitor is hyperSparc, a three-chip processor developed by Cypress Semiconductor, San Jose, Calif., and its Ross Technology subsidiary, Austin, Texas. Fabricated in CMOS, the set boasts a six-stage superpipeline, fed by an 8K-byte two-way set-associative instruction cache on the same chip. Its designers believe it will achieve 133 MIPS and 64 SPEC'92 SPECfp points. The three elements are the CY7C620 central processing unit (CPU), the CY7C625 cache controller/memory management/tag unit, and the CY7C627 cache data unit. With its five execution units, the CPU can fetch and execute two instructions every clock cycle, if they are of a type that will allow them to run simultaneously.

It is not clear which architecture will prevail. Cypress Semiconductor is betting that hyperSparc's less aggressive design and simpler process will be easier to debug and manufacture, thereby beating SuperSparc to market with faster designs. But although Cypress's first offering at 66 MHz is faster than TI's 40 MHz, TI has a production lead of several months and is already shipping SuperSparc in volume to selected customers. In the long run, SuperSparc's single-chip architecture may fare better against the latencies introduced by distributing signals over a multichip set. Cypress is working on tape-automated bonding and multichip modules to overcome interfacing problems.

PETITE PACKAGES. IC packaging, too, feels the push from the notebook and palmtop computer markets. The constant drive to miniaturize these machines has designers seeking out ICs and peripherals with the smallest possible footprint. The most popular form for notebook and palmtop peripherals are credit-card-sized modules conforming to the Personal Computer Memory Card International Association (PCMCIA) standard. Just 3.3 mm tall, these peripherals are too thin to enclose standard die packages, so extremely low-profile chips are a must.

Among the most popular form factors for volume-sensitive applications is the thin small-outline package (TSOP), approximately 1 mm thick. The number of TSOPs shipped by vendors as a percentage of all package types has steadily increased in the last year, especially in memory devices. Fujitsu Microelectronics Inc., San Jose, Calif., expects that 50 percent of its 4M-bit DRAM sales in 1993 will be in TSOPs, as against only 25 percent in 1992. "TSOPs are taking over with the same speed that SOJ [small-outline J-lead] devices overtook DIP devices," observed Larry Hester, strategic marketing manager with Fujitsu Microelectronics. His company has gone further and announced its ultra-thin small-outline package, which has a targeted thickness of 0.45 mm. These may be piggybacked into one package 1 mm tall, doubling the chip count in the same height as a conventional TSOP. Mass production of a 0.65-mm version is targeted for 1993, with the thinner version to follow after evaluation.

The third dimension has also been enlisted in the search for expansion. Irvine Sensors Corp., Costa Mesa, Calif., introduced a commercial version of its three-dimensional memory Short Stack. The company demonstrated a module consisting of four stacked 1M-bit (128K-by-8) static RAMs, in a 7.1-by-13.7-by-1.5-mm package. The dice are bonded together with a thin layer of adhesive, and the edge of the stack is given a thin-film metallization. The company has also demonstrated a Full Stack technology, which will support up to 100 ICs in a single package that can be solder-bumped onto a suitable substrate.

Reducing the number of components needed is another approach to minimizing board area, and hence product size. Zycon Corp., Santa Clara, Calif., has begun licensing its trademarked Buried Capacitance technology to selected printed-circuit board (PCB) manufacturers. Almost all electronic circuits fabricated on PCBs scatter numerous bypass capacitors throughout the design to reduce noise introduced into the power plane by switching transients. Zycon's product uses a patented copper-clad dielectric core sandwiched between the power and ground layers to capacitatively couple them up to 506 pF/cm^2 per layer. This simplifies board layout, reduces electromagnetic interference, and eliminates almost all bypass capacitors. Zycon notes, though, that some designs may need a few of them near noisy components like memory.

Besides size, interconnecting the packaged devices presents problems. Device interconnection technology has lagged behind increases in operating frequency, and at frequencies over 100 MHz, the impedance of device leads introduces significant delays between chips. Superconductor Technologies Inc. (STI), Santa Barbara, Calif., has demonstrated a superconducting multichip module (MCM) for silicon ICs. STI has demonstrated a ring oscillator constructed of nine CMOS inverters connected by 10-μm superconducting lines of high-temperature thallium film. It was tested at 77 K. ◆

Test and measurement

- **PC instruments getting more powerful**
- **Virtual instruments getting real**
- **VXI attracts non-U.S. firms**
- **Consortia encourage open systems**

During 1992, software-controlled, card-modular test and measuring instrumentation really took hold—and will likely hold its own for the rest of the 1990s. Most important, the number and variety of available instrument cards that fit into the VXIbus, plus the software to control them, reached critical mass last year, enabling test-system designers to assemble and program test setups for almost any imaginable application. And the personal computer—now powerful enough, familiar, available, flexible, low in cost, and industrially hardened—has become the obvious platform for the new instrumentation.

Thus, everything seems to have fallen into place in 1992 to fulfill not only the conventional standards such as RS-232, IEEE-488.2, and the *de facto* standards developed for the IBM PC, the Macintosh, and Unix-based workstations, but also the latest 1992 VXIbus standard (version 1.4), together with new powerful software and the latest 1992 version of the Standard Commands for Programmable Instruments (SCPI—pronounced "Skippy").

Although SCPI, an ASCII-type of protocol, is not an official standard, it is an expansion of the IEEE 488.2 standards describing the commands for a generic test-instrument system [Fig.1]. Designed to be layered on top of the hardware-independent portion of 488.2, SCPI can be used with interface hardware such as the VXIbus and RS-232. The generic system mixes off-the-shelf instruments that have SCPI-defined components with computer-derived computational analysis and displays.

Members of the SCPI Consortium, formed in April 1990, are all also members of the VXIbus Consortium, including Bruel & Kjaer Instruments, John Fluke Manufacturing, Hewlett-Packard, Keithley Instruments, Wavetek, Philips Test and Measurements, National Instruments, and Tektronix.

Executive director Fred Bode, an independent consultant in La Mesa, Calif., presides over SCPI, which meets every other month to review new commands, whether proposed by a member or anyone else. The group issues an updated version once a year, usually in March after a meeting in January; the latest version is SCPI-1992.

Bode also publishes a VXI newsletter; its August 1992 issue contains a complete list and description of all available types of VXI equipment (over 500) made by a large group of vendors—a testament to 1992 being the year that the software-controlled test and measurement instrumentation market took off.

As evidence of that growth, Bode explained to *IEEE Spectrum*: "It's hard to imagine a worse time for the overall electronics test and measurement industry. In the midst of this slow to no growth, though, VXI is doing just fine, thank you! Our current estimates show the total market for VXI products was just under $60 million in 1991, indicating a growth of about 100 percent from 1990. Prime Data estimates a 70 percent growth in 1992, with total shipments at $100 million worldwide."

Moreover, according to Ken Johnson, president of Testech Ltd., Oswego, Ill., a consulting and VXI seminar-production firm: "Not only did test-equipment manufacturers reach a critical mass in the availability of VXI-based modules in the 1991–92 time period, but also large government procurements of personal computer VXIbus systems, which had been years in the negotiating phases, suddenly were ordered in 1992, thereby greatly boosting the respectability of VXIbus among industrial users."

Johnson predicted that, with the large and still growing choices of VXI modules, the testing instruments for the rest of the 1990s will be adaptable enough to keep pace with advanced measurement technology and data acquisition, in-depth data analysis, and powerful and flexible presentation of results.

HIGHLIGHTS

Success: The PC-based instrument market, with US $1.3 billion revenues in 1991 worldwide, is projected to pass $2.4 billion by 1998.

Shortfall: The VXI mainframe alone was priced at over $6000, and modules often cost 30 percent more than conventional units.

Notable: LabVIEW, which can simulate almost any type of measuring instrument in software, made virtual instrumentation practical.

Newsmaker: Latest VXIbus Revision 1.4 included more detail on such issues as dynamic system configuration that helped designers better interpret the specification.

One of the many fruits in the 1992 VXIbus orchard is the Government's US $1.2 million contract to Ascor, Fremont, Calif., an active VXIbus house, for the consolidated automated support system (CASS) automatic test equipment (ATE), designed with modularity and flexible enough to troubleshoot almost everything in the U.S. Navy's electronics inventory. Another major VXI-based testing system is the $1.5 million order from Tektronix Inc., Beaverton, Ore., for the VXI/ Smart system, and the first to use the Atlas standard modular avionics repair and test (Smart) software for testing DC-10 autopilot electronics. Of course, hundreds of smaller VXI-based systems are also in use.

On top of all that, 1992 was the start of the PC-based era in instrumentation because, according to a May 1992 report on this market overall by Market Intelligence Research Corp., Mountain View, Calif., the $1.3 billion in sales revenues recorded in 1991 worldwide is expected to almost double to $2.4 billion by 1998, growing at a 9.5 percent compounded annual rate.

"Thus, the personal computer has become an increasingly important contributor to industries involved in measurement-control applications," the report states.

It also points out that the large installed base of PCs encourages instrument manufacturers to take advantage of the off-the-shelf technology and software developed originally for those machines, such as the huge inventory of programs available based on the Microsoft disk-operating-system (MS-DOS), the Macintosh-operating-system, and Unix.

Although many testing systems had been connected to PCs since the 1970s by use of the IEEE-488 standard interface, performance was limited by the then-available PC's low memory and processing rates. But during 1990–92, the newer 16- and 32-bit machines that became available have very large memory capacities, much higher speeds, and excellent high-resolution display capabilities. Those important features, plus the inherently user-friendly environment associated with desktop machines, has added to their appeal for controlling test instruments.

Furthermore, integrating PCs with instruments through plug-in boards and the disk-storage of data is extremely cost-effective and versatile. Finally, new software that facilitates menu-driven interfaces, graphic displays, and data manipulation is vastly

Morris Grossman Contributing Editor

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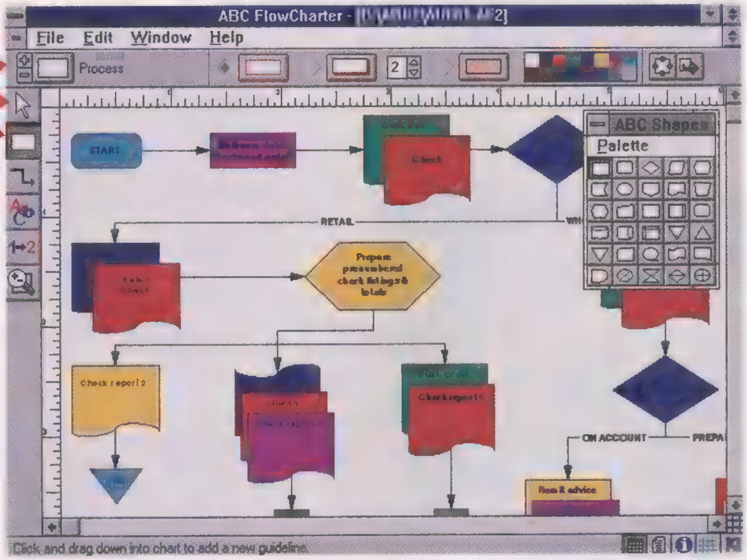

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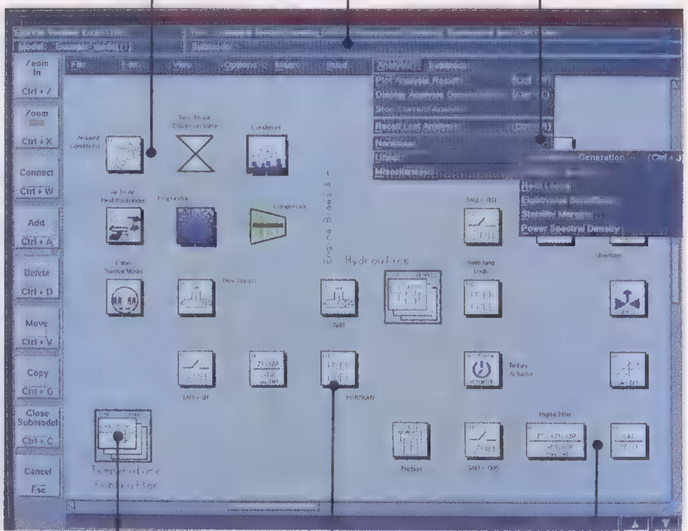

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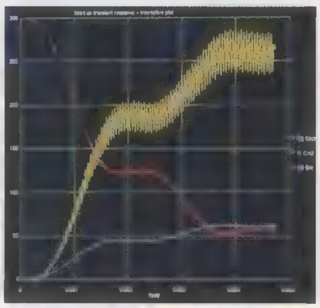

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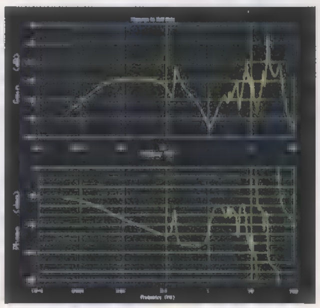

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improved over that for the more conventional ATE rack-assembled fixed-application-instrument approaches.

SOFTWARE ALSO IN PLACE. One source of software that has helped promote this upsurge in PC-controlled testers is National Instruments Corp., Austin, Texas. The company's latest package is LabVIEW for Windows, Version 2.5 for IBM-PC and compatibles outfitted with Microsoft's Windows [*Spectrum*, October 1992, p. 74]; others include LabVIEW for the Sun Workstation and LabVIEW for the Macintosh.

Originally created as a general-purpose programming language for laboratory instrument control and data analysis, the software has since bloomed into many applications for a wide range of machine and process-control problems.

"In 1983, when the development of LabVIEW began for the Macintosh, there was a tremendous gap between the time to physically assemble a conventional instrumentation system and the time to program that

EXPERT OPINION: The key to better measurements is software

JOHAN SCHOUKENS, MARC VANDEN BOSSCHE, AND RIK PINTELON

With the introduction of the IEEE-488 bus at the start of the '70s, a new era dawned in instrumentation technology. Before, making measurements by hand and writing them down on paper was a slow and tedious job. After, mountains of data could be swiftly collected from several different measuring instruments and stored in a computer. Overnight the problem changed from a scarcity of time to what to do with this superabundance of data. The answer was found in digital signal processing (DSP).

At about the same time, the emphasis in measuring instruments changed from analog to digital devices. Analog test instruments inherently limit the parameters that can be measured to voltage, current, frequency, and phase. Digital instruments, on the other hand, derive their answers from digital-signal–processing algorithms that require measuring more sophisticated, nonphysical parameters, such as the poles and zeros of transfer functions embedded in very complex models.

This change to digital circuits resulted in the development of complex mathematical DSP tools. Such sophisticated instruments as dynamic signal analyzers, fast Fourier transform analyzers, and microwave analyzers help to interpret the heaps of data today's test instruments quickly gather.

Of course, the shift from analog to digital instruments affects the internal structure of the measurement equipment. A typical instrumentation configuration consists of a signal generator, a data acquisition arrangement, and a data-processing part, which extracts the parameters of interest from the raw data. Understandably, the sensor and actuator technology of the data acquisition circuitry are closely connected to the application, while the data-processing part is only loosely coupled to a specific application. Nevertheless, the impact of data processing on the final outcome of the measurements is most important.

An unfortunate side-effect, though, is that the "distance" between the measured raw data and the finally delivered quantities has become vast; users often fail to grasp the significance of the results. Moreover, as they do not fully understand how their instruments operate, they are at risk of using the devices improperly or inefficiently, and then may not even notice that erroneous measurements have been made.

To reduce the danger of equipment misuse and to guide the user in obtaining correct measurements, a simple expert system should be added to these instruments. Such a built-in helping hand would enable a larger class of users than are now qualified to do so, to run complex instruments properly. That kind of help could not only simplify the daily life of the engineer, but also enlarge the possible market for the manufacturer.

For example, DSP can use the large quantities of raw data to cut back on random measurement errors. First, as the number of measurements increases, a good averaging algorithm would cause the averaged value to converge toward the exact value. The design of such an algorithm is a critical step in the development of a good digital instrument.

Also, identification theory offers a general framework for the development of algorithms called estimators. These minimize the bias (offset errors due to noise) and the uncertainty of indirectly measured physical parameters. Still, good instrument design is advisable for two reasons: first, it minimizes systematic instrument-measuring errors, and second, it maximizes the signal-to-noise ratio of the raw data and thus helps reduce random and bias measurement errors.

Clockwise, from the top: Schoukens, Vanden Bossche, Pintelon

'In the future, the restrictions of instruments will move more and more from the hardware to the software side.'

Another important use of DSP is to simplify and enhance test-instrument circuitry. Classically, trimmed circuits were used to adjust an instrument's characteristics to desired specifications. However, recently available DSP chips can be adjusted with software to compensate for some off-spec parameters. This feature greatly simplifies an instrument's overall hardware design and allows looser specifications.

For example, in the design of an anti-aliasing filter, instead of designing a complex analog, high-order, low-ripple filter, which needs careful trimming, the manufacturer can build a much simpler low-order, high-ripple filter with nonselected components and without trimming elements. Then, a software-controlled, compensating digital filter can bring the overall dynamic characteristics of the instrument within the desired specifications.

Obviously, this changing viewpoint—the use of software-controlled DSP circuits—drastically influences the design requirements and shrinks production costs. In the future, the restrictions of instruments will move more and more from the hardware to the software side. Instrument users will then be able to exploit fully an instrument's increased flexibility and to customize the instrument by adding home-brewed algorithms internally.

However, traditional manufacturers have done their utmost to stop their customers from playing around with their instruments' internal structure. This attitude has persisted despite the fact that instruments now can solve ever more complex problems, but almost never the specific problems of their customers. Merely exporting the available data out of instruments and forcing the user to interpret or modify it afterward was a natural response of manufacturers. That approach was the only clear separation between the responsibility of the manufacturer and that of the customer.

A solution lies in a newly burgeoning approach: use of personal computers with instruments on boards. But a large gap still exists between hardware configurability and the software structure.

Next-generation instruments will have a widely supported software architecture that reflects the hardware components and their interactions. This will be done, we believe, with object-oriented programming.

Johan Schoukens (M) and Rik Pintelon (M) are research associates of the National Fund for Scientific Research at the Free University of Brussels, Belgium. Marc Vanden Bossche heads a research group at the university.

system," recalled James Truchard, president of National Instruments. LabVIEW, with its icon and graphical approach to programming, helped solve that problem.

But PC-DOS types of computers, although far more prevalent, lacked the graphics capability of the Macintosh. Accordingly, LabWindow, which runs on DOS 3.0 or higher, required Microsoft C or QuickBasic text-type languages to develop testing programs for it. LabWindow has extensive libraries of functions for data acquisition, analysis, and presentation, along with tools for editing and debugging programs.

The LabWindow software can acquire data from plug-in data-acquisition boards or control almost any type of measuring instrument outfitted with an IEEE-488, RS-232, or VXIbus. Graphs, strip charts, switches, and many other controls can be displayed on the PC's monitor in many formats, sizes, and colors. Also, the computer can display images stored in PCX format to illustrate diagrams of test systems, schematics, or the flow of a process control system.

With the advent of Microsoft Windows for DOS, however, a PC-DOS machine can now also be programmed graphically, much as LabVIEW programmed the Macintosh. It can fit into a personal computer that has at least an 80386 processor and compatible 80387 coprocessor, 8 Mbytes of main memory, 10 Mbytes of free hard-disk space, Windows 3.1, DOS 5.0, and preferably a VGA display. Now there is also a LabVIEW version for the Sun workstation—thus, there has been a coming together in 1992 of many powerful software packages.

Still, a large group of workers in the test and measurement field prefer the Macintosh as a base for their instrumentation. According to Andrew Agoos, president of Software Engineering Group, Cambridge, Mass., "The supply of industrial-strength hardware and software tools for Macintosh users is steadily increasing...It means that the Macintosh, often called by its promoters 'the computer for the rest of us,' is making it easier than ever to bring friendly and efficient automation to the plant floor."

He explained that the Macintosh operating system is designed with consistency and extendability, which reduces the learning curve for new applications. "Although Microsoft Windows [which operates under DOS] has superficial similarities to the Macintosh, Windows still lags in application-to-application consistency," he added.

Agoos believes that LabVIEW is the most comprehensive software system package available today, one that can simulate almost any type of measuring instrument in software. "We finally have the arrival of a practical virtual instrumentation package," he said.

SOFT INSTRUMENTS. LabVIEW allows users to quickly create graphically based control-and-monitoring virtual-instrument systems merely by calling them up to the computer's display—dials, gages, switches, meters, tanks, strip charts, and stand-alone instruments. Then, with the proper transducers, data-acquisition boards, and other circuitry in place, an instrumentation system quickly comes together. The setup can be designed and redesigned right from the computer's keyboard.

A virtual instrument is simply a software module packaged to have the look and feel of a physical instrument ["An instrument that isn't really," *Spectrum*, August 1990, pp. 36–39]. The computer display can be of a stand-alone instrument like an oscilloscope with its familiar knobs, switches, and scope display, or it can represent the controls of an ATE setup, or of a set of monitoring devices [Fig. 2]. A user interface can be created regardless of the hardware involved; the software becomes the instrument.

The National Instruments software features functional icons that are simply placed within an on-screen program window and connected in a desired measurement setup. The icons contain instrument variables, measurement commands, and output designations. Test-code documentation can be printed or viewed at any time with a description of the program functions.

But National Instruments is not alone in supplying software for test equipment. WaveTest software from Wavetek Corp., San Diego, Calif., can transform flowcharts into IEEE-488 or VXI program-control routines. The software's instrument library encompasses hundreds of instruments from more than 20 manufacturers to provide a graphical syntax-free test-instrument code. WaveTest runs on an IBM PC outfitted with at least an 80286 microprocessor, 1M byte of RAM, 5 megabytes of hard disk, Windows 3.0, and at least an EGA display.

HARDWARE NEEDED. Naturally, the software cannot do the whole testing job by itself. It needs interfacing instrumentation hardware, and the hardware for the test system needs a base from which to work. One of the items previously mentioned that "fell into place" last year was the VXIbus, an extension of the VMEbus to instrumentation.

Five years earlier, the VXIbus Consortium was formed by five instrument manufacturers—Hewlett-Packard, Tektronix, Colorado Data Systems, Racal-Dana Instruments, and Wavetek. The group jointly announced a VMEbus-based instrument-on-a-card specification, now updated by the latest Revision 1.4. Presently presided over by David Haworth, the VXI program manager at Tektronix, the consortium noted that VXIbus is supported by at least 40 manufacturers, including National Instruments. At least 120 other companies have announced plans to support the bus, and over 500 products incorporate this evolving standard.

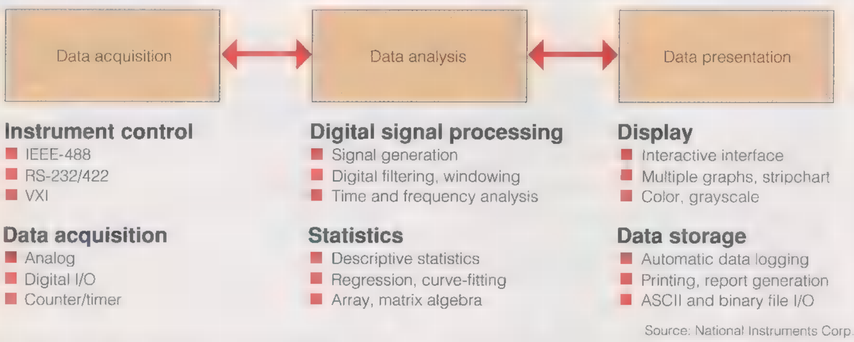
VXI has also attracted the interest of non-U.S. instrument makers such as the Japan Electric Measuring Instrument Manufacturers' Association (Jemima), Tokyo, which has formed a working group to review the VXIbus specifications. Several European companies are also looking into VXI.

Revision 1.4 adds numerous changes to the 1.3 version. Through extensive interoperability testing, the consortium identified several issues that needed additional explanation to help designers in interpreting the specification. The issues, ranging from mechanical and cooling aspects to dynamic system configuration, are now explained in greater detail, and the standard's fast-handshake protocol has been refined.

Also, the VXI consortium has published a number of new specifications that are intended for use along with the baseline specification VXI-1. National Instruments (along with most of the other VXIbus consortium companies) offers a VXI booklet explaining the new Revision 1.4 of the baseline VXI-1 specifications.

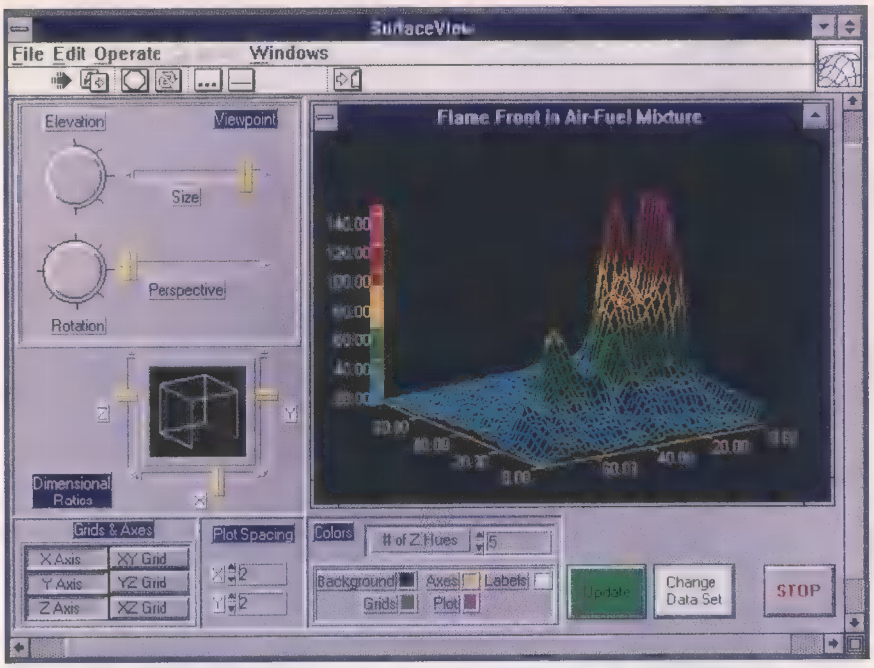
With proper software, the VXI readily lends itself to the virtual-instrument concept. For instance, the Type 3538 Modular Test System from Bruel & Kjaer Instruments Inc., Marlborough, Mass., which conforms to the VXIbus specifications, features a wide variety of virtual-instrument modules. Software then combines the modules into different instruments as required by a particular application.

Because the supported board instruments meet a common interface specification, a large selection of circuits can be assembled



[1] Generically speaking, acquisition, analysis, and presentation are the three main elements of a test-instrument system. Each has its own set of requirements, such as instrument control and digital signal processing. The Standard Commands for Programmable Instruments, an ASCII-based language, is layered on top of the hardware-independent portion of the IEEE-488.2 standard to provide the commands for making all the elements play together.

National Instruments Corp.



[2] A virtual instrument is simply a software module packaged to have the look and feel of a physical instrument—a stand-alone instrument, or the dials, gages, switches, meters, tanks, strip charts, and a set of monitoring devices.

as needed for a particular test system. An oscilloscope, a digital-multimeter, and a signal-generator board, say, could be combined with a switch-controller board—with all controls displayed on the computer's monitor under software control—to provide a complete virtual test-bench setup. Or by rearranging or replacing the circuit card selection and modifying the software, an engineer could quickly provide another type of setup.

But such an advantage is not without its cost. A VXIbus system starts at about $6000 (according to Tektronix) for the VXI card cage, backplane, and power supplies, before even buying one instrument for the system—and engineers and scientists might have second thoughts about picking the VXIbus to start a testing project.

Moreover, some VXI instruments cost as much as 30 percent more than their rack-and-stack counterparts. But once this high up-front price is paid, the development of a VXI-based testing system can cost much less than would building the usual rack assembly for a specific application. And the savings grow as a test-system designer becomes more familiar with VXI, uses it for many projects, and employs the same VXI mainframe and instruments again and again.

Furthermore, in time the cost of instruments and software for VXI systems will surely come down. For instance, Racal-Dana Instruments Inc., Irvine, Calif., already offers a time-interval analyzer and a microwave counter that each cost about 40 percent less than competing conventional units.

OTHER CONSORTIA. Although Hewlett-Packard was a charter member of the VXIbus Consortium and is still an ardent supporter, it nevertheless formed a modular measurement system (MMS) consortium with five other companies (now three more have joined), and continues to promote its own HP-70000 MMS as "especially suited for high-frequency RF, microwave, and lightwave applications."

Besides HP, the MMS consortium originally included General Microwave, Marconi Instruments, Microsource, Martin Communications, and Tern Technology. Joining the group recently has been General Electric, Grumman, and Martin Marietta. Duane Hartley, general manager of Hewlett-Packard's Microwave Instrument Division, Santa Rosa, Calif., said that "MMS handles high-frequency electromagnetic interference better, is more compatible in electromagnetic shielding, and offers a lower life-cycle cost than VXIbus equipment."

Nevertheless, compatibility with VXI is a key goal. A test engineer may choose MMS for RF and microwave work and VXI for low-frequency analog and digital needs, according to Hartley. Thus, MMS is an open standard and patents have been dedicated to the public; anyone may build onto the system without license or fee.

The April 1991 MMS Consortium catalog now offers more than 40 MMS modular components, including mainframes, displays, modules, and systems. There are also more than 4200 MMS-based instrument mainframes in worldwide use, half outside the United States; over 75 percent of the global total are commercial customers.

Major defense projects that included MMS equipment were CASS (previously mentioned), Grumman Corp.'s Intermediate Forward Test Equipment (IFTE), McDonald Douglas's and Honeywell's Intermediate Support System (TISS) for the Air Force's Tactical Electronic Warfare System (TEWS), and Martin Marietta's Low Altitude Navigation and Targeting Infrared Ranging System for Night (Lantirn).

However, engineers at EIP Microwave Inc., Milpitas, Calif., have demonstrated that the VXIbus is no slacker at microwave frequencies with its 114A frequency synthesizer, which operates over the 2–20-GHz range. The synthesizer, packaged for VXI, features 1-Hz resolution over the total range with excellent spectral purity. Thus, the VXI is a viable alternative to MMS.

Still another instrument consortium, formed in 1990, is the Personal Computer Extension for Instrumentation (PCXI), headed by Rapid Systems Inc., Seattle, Wash. The PCXI "standard" includes all the items needed to turn the bus of a desktop computer into an industrial testing instrument. A special passive backplane accepts any IBM PC instrumentation, control, or data acquisition card that meets the Industry Standard Architecture (ISA) on which the IBM PC is based. The cards fit into metal-shielded modules that plug into the backplane. A recent revision of the standard, PCXI-1991, adds the 32-bit Extended Industry Standard Architecture (EISA) bus.

Despite outward appearances that the PCXI Standard competes with the VXIbus standard, Rapid Systems' president Soren Vestergaard said, "The two standards are complementary. PCXI does not have the performance range of VXI, but it is a lower-cost, simpler way of putting together a test set or even an ATE for some less demanding applications."

Although PCXI is still not a full-fledged, completely defined, and formal standard, over 40 companies, including AT&T Bell Laboratories, Boeing, Ciba-Geigy, Eastman Kodak, and Texas Instruments, have used PCXI to control their instruments.

WORKSTATION TRIUMVIRATE. But the test and measurement industry has seen many new consortia and alliances formed in the last few years—an interesting and important development. According to Tom Lee, marketing manager for Tektronix Inc.'s measurement solutions product line, an alliance to develop, market, and sell a new line of integrated test and measurement systems worldwide was formed on Sept. 1 last year by Sun Microsystems Computer, Tektronix, and National Instruments. However, instead of a desktop controller and display unit like the DOS PC or the Macintosh, the new line of instruments will use more powerful Unix workstations from Sun.

Although the alliance named its product line Open Measurement Solutions (OMS), the group is a private one, not a consortium open to all. Nevertheless, the new alliance has an open-system approach, Lee explained: "This is the best way to attract customers. The new solutions, on a single workstation platform, will readily link with equipment from multiple vendors and expand to meet a user's future needs." ◆

Industrial electronics

- CNC resolves a nanometer
- Sequential functions favored for PLCs
- Vision chip detects edges faster
- X-rays diagnose flaws in surface-mounted boards

Does industrial automation improve competitiveness in manufacturing, or does the search for competitiveness boost automation? Either way, users in the United States alone spent nearly US $40 billion on equipment of this kind in 1991, according to the 1991 Industrial Automation Investment Profile, a report released in October by the National Electrical Manufacturers Association, Washington, D.C. Vendors of machine tools in the United States, however, fared worse in 1992 than in 1991. The Association for Manufacturing Technology, McLean, Va., reported that in the first nine months of 1992 machine tool sales in the United States amounted to about $1.87 billion, a fall of 2.9 percent from the same period a year earlier.

In spite of a generally torpid global economy, industrial electronics made some notable advances. They include improved precision in computerized numerical control (CNC) for machine tools; easier, high-level programming for programmable logic controllers; faster and more efficient machine vision; reduced false accept and reject ratios in X-ray laminography for the examination of solder joints, particularly in surface-mounted boards; and high-wattage power electronic devices.

The complex milling involved in, say, die machining and the grinding of precision optical components may now be done with a resolution of 1 nm. At any rate, the Series 15-B CNC, introduced in October by GE Fanuc Automation North America Inc., Charlottesville, Va., achieves 10 times the resolution of previous technology. This resolution is due to the use of high-precision sensors, along with two 32-bit processors (MC68EC030) operating in double precision (64 bits) at 33 MHz, and a serial feedback to the CNC control. Traditional position servo feedback cannot attain this precision because it would require a relatively high pulse rate for position increments beyond the circuit's capability, or, alternatively the processors would be kept so busy that the cutting rate would slow. Serial feedback solved this problem, according to a GE Fanuc spokesperson. For example, with the traditional feedback the position servo encoder might transmit some 4000 encoded pulses in 250 μs, he explained. With the serial feedback, in contrast, only one position message is transmitted every 250 μs, requiring less than 80 bits, thereby freeing the processors for the double precision task. The 1-nm precision smoothes the operation of machine tool servo axes, and hence enhances the surface quality of machined parts.

Gadi Kaplan Senior Technical Editor

Nor is that all. A high-precision contour control (HPCC) feature included in the GE Fanuc Series 15-B CNC reduces error in machining sculptured die surfaces. An automatic feedrate control is one of several HPCC functions. Basically, it allows the user to indicate how far the path may deviate from the one specified for a given part. When the contour control is activated, the CNC processes up to 60 blocks of the part program ahead, to be ready for highly curved portions of the design, and modifies the feed rate and acceleration or deceleration of the workpiece to keep the actual path of the cutting tool within a specified tolerance of the commanded path [see illustration]. Additionally, faster cutting is bonus to those users who go for the HPCC's reduced-instruction-set (RISC) microprocessor option.

Finally, adaptive control is another significant new feature in the Series 15-B. Embedded in the CNC's load monitor library software, it enables the cutting tool to adapt to load changes, thereby reducing its wear.

An easy-to-expand operating system is the Delta 30M's main claim to fame, according to Autocon Technologies Inc., Farmington Hills, Mich. The 32-bit CNC was introduced last September at the International Manufacturing Technology Show in Chicago. It came about as a result of the CNC's built-in nonvolatile flash memory, whose popularity has risen recently as a result of falling cost per bit. Flash memory can be reprogrammed by the user while it is in the circuit. This is particularly important for updates of the operating system, which Autocon now supplies on 3.5-inch floppy disks that are easily read by the CNC's disk drive. To reprogram an erasable electrically programmable ROM (an earlier nonvolatile memory), the user must first remove the board on which it resides and send the lot to the factory. To make off-line programming easier, Autocon has offered PC-based part programming software that can translate programs from one vendor's format into another.

PROGRAMMING PLCs. With an eye to enlarging their market share, vendors of programmable logic controllers (PLCs) pay a lot of attention these days to improved graphical user interface (GUI), to ease of programming and error correction, and to communications capabilities. For example, GE Fanuc teamed with Adatek Inc. in Sandpoint, Idaho, to offer natural-language state logic control of GE Fanuc's series 90 PLC. Users with hardly any programming experience may program the PLC in their own natural-language terminology or wording, the company claims. GE Fanuc also offers programming in such high-level languages as Basic and C, which appeal to the computer-literate control engineers and have become more prevalent in the industry.

The use of sequential function charts is nudging relay ladder diagrams to the side in PLC graphics displays, more so in Europe, where typical PLCs abide by the French Grafcet standard. In the United States, however, people tend to cling to the old relay ladder diagrams because here "the user is more conservative," said Timothy L. Johnson, manager of the Control System Laboratory at General Electric Co.'s R&D Center in Schenectady, N.Y. The biggest benefit of the new GUI is the ease of making changes, Johnson noted, particularly in those all-too-common situations where the original programmer has moved on to a new position without leaving a clue to his or her software design.

The latest generation of PLCs attains a new level of flexibility through use of several processors, which let several tasks run simultaneously. Allen-Bradley Co., a unit of Rockwell International Corp., Milwaukee, Wis., introduced a new line of control

HIGHLIGHTS

Success: VC-2, a new machine vision chip by Cognex Corp., trims 80 percent off a critical computation time.

Shortfall: Intelligent robots and intelligent manufacturing systems failed to live up to expectations.

Notable: Interest in micromachining is growing worldwide, with experimental devices developed by several laboratories.

Newsmaker: The National Electrical Manufacturers Association in the United States reported an investment of nearly US $40 billion in industrial automation equipment and services in 1991, up $7 billion from 1989.

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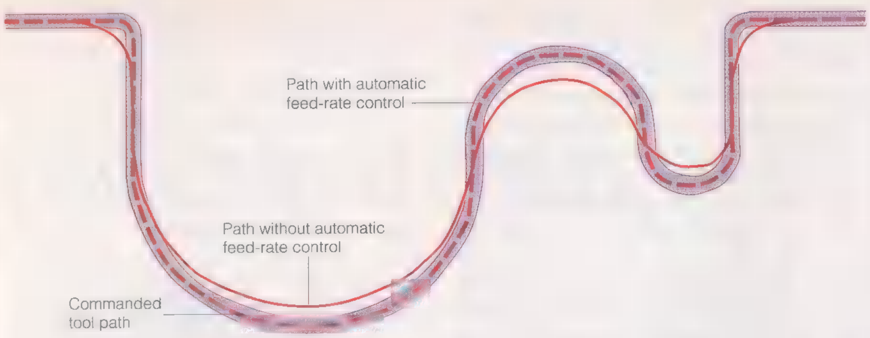


Automatic feed-rate control in GE Fanuc's Series 15-B computerized numerical control ideally keeps the cutting tool within tolerance, thereby reducing the machining error in high-curvature parts. In practice, however, the cutting path may deviate slightly from the ideal path because of lag along one or more of the axes [not shown].

coprocessors called the 1771-DMC and DMC1.

The control coprocessors target applications in need of a true real-time control platform that can complement the PLC ladder logic. Programs written in C, Basic, or assembly code run independently of and asynchronously with the PLC; alternatively, relay ladder logic instructions can be used to start and stop them. The coprocessor also takes advantage of a new communications port on the company's PLC-5 processors for a direct connection to data table information.

Networking, communications, and, indeed, distributed control by PLCs are also moving forward, as reflected in products introduced by Siemens Industrial Automation Inc., Alpharetta, Ga., and Omron Electronics Inc., Schaumburg, Ill. Siemens introduced its ET-200 distributed I/O system, which complies with the international Fieldbus standard. Both its block version (ET-200B) and its modular version (ET-200U) can be located up to 3000 meters away from the central controller without a repeater.

Omron's series PLCs (CV 500 and 1000) have multiple buses and multiple processors designed to work on the company's high-speed distributed-control network. For example, the CV1000, the faster of the two, executes on average one instruction every 120 ns, a rate the company claims is the fastest among PLCs with a similar number of I/O points (4096).

Another significant new feature in Omron's new PLC family is the capability for

EXPERT OPINION: Mechatronics on the move

FUMIO HARASHIMA

New technologies relying on fast computer performance have changed and in their changed form will continue to exert significant influence on the development of industrial electronics. Artificial neural networks are being introduced in industrial products, as is fuzzy logic, which is especially likely to be applied extensively in interfaces between machines and humans, rather than strictly in process control.

Great expectations of intelligent robots and intelligent manufacturing systems have as yet failed to materialize. Instead, companies are starting to concentrate on mechatronics, a more conservative mechanics and electronics combination, and on motion control technologies, in order to tune a variety of machines to special purposes.

Microprocessors are seemingly ubiquitous. Virtually every numerically controlled machine or industrial robot is equipped with at least one, in most cases complete with its own display screen and keyboard. The microprocessors exert full digital control over the manufacturing process and in addition "network" with other computers in the factory.

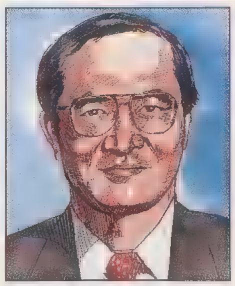
Many products by Japanese manufacturers are based on mechatronics. Moving parts and everything else are controlled by specialized very large-scale ICs integrating a microprocessor with the amplifiers necessary for such applications as small electromotors for autofocus or for tape transportation. Japan's 10-year project on Intelligent Manufacturing Systems (IMS), started in 1990 by the Ministry of International Trade and Industry, is pushing ahead fast. It will analyze the present state of automatic manufacturing technology and point to new ways to go from here.

Micromechatronics, meanwhile, is just beginning. A complex integrated micromechatronic system has yet to be developed, as much more research is needed on actuators and sensors. Research laboratories in universities and industry recently made very successful microsensors with micromachining technology. In October 1991 the Japanese Government started a large national project (spending 15 billion yen for 10 years) to support innovation in micromachine technology.

Japan's early start and sustained effort in fuzzy logic and artificial neural network research have had a definite impact on industrial products. Several Japanese semiconductor manufacturers have developed fuzzy logic or artificial neural network processing chips in their research facilities and are beginning to introduce them as products on the market.

Visualization technology, including virtual or artificial reality, has come to the fore in leading industries, along with powerful graphics workstations. During the design phase of new products many questions can now be answered by computer simulations and the application of virtual realities, combined with very fast, three-dimensional graphics workstations. All these are tending to shorten the product development cycle. Prototypes can be often evaluated on the workstation's screen, reducing the need for physical models of the final products.

Meanwhile, advanced research in industrial automation is charting the flow of information and electric power between users and machines in interactive systems. One problem is how to exchange visual information from, say, a camera based on charge-coupled devices (CCDs) with readings from force or tactile sensors. For example, a recent research project on an intelligent assisting system (IAS), being conducted by Hideki Hashimoto and this author at the University of Tokyo, splits a robotic automation system task into two distinct parts—an intelligence intensive part and a skilled manipulation part. Thus, using a comfortably sized input device, an operator could be present in a microenvironment, handling very small molecules with a micromanipulator, and letting the IAS perform the necessary man-machine transformations. Having intelligent knowledge about tasks to be executed, the IAS may also carry out manipulations automatically.



'The advancements of mechatronics and automatic manufacturing equipment have greatly enhanced production efficiency. Very much less need be done by employees in the way of physical work.'

The advancements of mechatronics and automatic manufacturing equipment have greatly enhanced production efficiency. Very much less need be done by employees in the way of physical work. In many countries this is a highly controversial topic. But in Japan, workers are delighted to have their new "colleagues" do all the hard work for them.

Fumio Harashima (F), a professor of electrical engineering and director of the Institute of Industrial Science, University of Tokyo, is coauthor of three books and has published more than 500 technical papers. He wishes to convey his special thanks to Hideki Hashimoto and Martin Buss for their help in preparing this article.

multilevel communications—up to three levels in a hierarchy—without the need for a special communications programming.

EFFICIENT VISION SYSTEMS. Ever shorter execution times are the goal of the latest machine vision systems. After all, accelerated (yet highly reliable) part inspection is needed to keep pace with today's high-speed production equipment.

The VC-2 computer vision chip by Cognex Corp., Needham, Mass., executes the Sobell edge detection algorithm for an entire image—a critical image-processing computation—in less than 40 ms, as compared to more than 250 ms without the chip, thereby boosting the processing of all Cognex vision software tools that employ the Sobell edge detection. Dedicated to this and similar image- processing computations, the VC-2 chip saves the end-user substantial programmming time by implementing the algorithms in hardware.

A massively parallel array of up to 512 processors working with a Motorola 68030 central processing unit (CPU) and 68882 floating-point processor, are at the heart of the EX series of vision systems from Applied Intelligent Systems, Ann Arbor, Mich. The company said its systems visually inspected such products as surface-mounted boards in about one-sixth of the time required by other systems. There is literally a price to pay, however—the EX series systems cost anywhere from $19 000 to $40 000.

Among the more specialized machine vision systems is one for inspecting the bonded wires of ICs. Developed by engineers with Fujitsu Laboratories Ltd., Atsugi, and Fujitsu VLSI Ltd., Gifu, both in Japan, this machine inspects each gold wire and associated ball in 200 ms. With a measurement accuracy of 5 μm, it rivals a human operator's performance and is being used on Fujitsu's production lines.

Analog vision chips are a specialized but as yet experimental vision advance. Researchers at the Massachusetts Institute of Technology in Cambridge developed them for tasks like image filtering, edge detection stereo depth determination, and camera motion determination. Very high frame rates and savings in chip area and power are the advantages of this analog VLSI approach to vision hardware.

X-RAY INSPECTION. Precision and throughput increased last year among X-ray laminography and radiography systems, which probe the inside of solder joints. Laminography shows layers within the joint, as opposed to radiography which, like a conventional medical X-ray, shows its overall consistency. Two competing companies have announced improvements in their new systems, emphasizing applicability to surface-mounted printed-circuit boards. They are Four Pi Systems and IRT Corp., both in San Diego, Calif.

Refined positioning of the printed-circuit assembly under test is a feature of the 3DX Series 3500G, an X-ray laminography system from Four Pi Systems. As a result, it accepted fewer bad parts and rejected fewer good ones when the components had lead pitches down to 0.3 mm. A new drive system was responsible. Its high-resolution ball screws and rotary encoders quadruple the positioning accuracy of tested boards to within less than 20 μm for the x and y axes, and for the z axis (important for focal cross sectional plane adjustment), it is less than 5 μm. In addition, the X-ray source in the Series 3500G is double the size of the source in its predecessor, and the throughput is now three to four times greater, depending on the application.

IRT produced a VME-based version of its CXI-3300 in-line X-ray radiography system, which is designed for production use in pass-through operation, following re-flow ovens. Running on an OS-9 operating system and networked to a Sun workstation, the new X-ray system inspects solder joints up to 50 percent faster than its DOS-based predecessor. The System resolves pitches as small as 0.2 mm, the company said.

LOWER 'ON' VOLTAGE. With their costs falling and performance steadily climbing, power electronic devices and systems are attracting growing interest, in anticipation of more efficient controls of ac motors and other industrial applications. Among the main attractions are the lower voltage drop of the newest devices when turned on, plus the ability to control motors and other manufacturing equipment with a virtually unity power factor on utility lines. One of the new devices is an MOS-controlled thyristor (MCT) with a typical 1.2-V forward voltage drop. The MCTV75P60E1 was introduced by the Harris Semiconductor Division, Mountain Top, Pa. For comparison, the typical forward voltage drop of an insulated-gate bipolar transistor (IGBT), a competing device type, is about 3.2 V, leading to far higher energy losses, considering how many hundreds of amperes flow in the device in a typical application.

Toshiba Corp., of Tokyo, in effect fought back. It announced an experimental IGBT with less of a voltage drop when conducting. While the device has yet to be commercialized, Bimal K. Bose, professor at the University of Tennessee in Knoxville and a well-known expert in power electronics, expects the competition between these two device types to heat up. "Future war between IGBT and MCT is certain," he told *Spectrum* in early November. On the systems side, researchers with Munich's Siemens AG and Hitachi Ltd. of Tokyo developed multimegawatt double-pulse-width-modulated converters using gate-turnoff thyristors in place of cycloconverters for drives. The converters have a unity power factor on utility lines.

As for fuzzy logic and neural networks they are "yet in their infancy" in power electronics applications, according to Bose. Research in artificial neural networks has shown good results in learning nonlinear mappings and in fault detection. One application in industrial electronics is their use in conjunction with intelligent sensors to diagnose defects on compact discs at WEA Manufacturing Co., Olyphant, Pa. Stamped with pits 0.5 μm wide in ultra-clean rooms, the CDs are extremely vulnerable to airborne contaminants, A speck of dust of only 1 μm can destroy the music tracks. The system at WEA employs sensors along with the neural networks not just to detect these defects but also to instruct the operator to tune the recording system to compensate.

Finally, if today's R&D bears fruit, a year or two from now may see neural-network systems used to diagnose rotating machines like pumps, motors, or compressors, or to restore distorted images, among other applications. Research on machine diagnostics is being pursued in such institutions as Tokyo's Hosei University and South Korea's Postech in Pohang and Hyosung Industries Co. in Seoul. Image restoration is being worked on at Japan's Yokohama National University, among other places, as reported during the IEEE's 1992 International Conference on Industrial Electronics, Control, Instrumentation and Automation (IECON '92), held last November in San Diego, Calif.

For example, Hosei University researchers built, simulated, and successfully tested a hierarchical neural-network system that diagnoses failures of ball bearings in a rotating machine. Its basis: spectral analysis of the machine's scream, the sound it emits as a result of the faulty bearings. The system has two neural-network stages: the first processes the sound by mimicking the auditory nerve; the second sorts out the ball bearing's standard number—4 digits that correspond to such specific physical parameters as the number of balls, their diameter, and their pitch. The researchers found that the hierarchical networks are simpler to train than other configurations because each stage in the hierarchy can be trained independently of the rest.

A back-propagation neural net was successfully used by the Postech researchers in Pohang to diagnose imbalance, misalignments and loosening of bolts in rotating machines. The diagnosis is based on the measurement of the power spectrum of the machine's vibrations, as picked up by an accelerometer, and on the extraction of feature vectors that characterise these conditions, much like feature extraction in speech recognition systems. The researchers are now working to refine the system to diagnose more complex cases with combinations of more than one abnormality.

A back-propagation neural net is also at the heart of Hyosung Industries' proposed system for monitoring the aging of electrical motors and Yokohama National University's system for image restoration. In the latter, the neural network works as a nonlinear filter. The researchers reported an improvement of nearly 2 dB in the signal-to-noise ratio of the restored image. ✚

Power and energy

- **U.S. energy bill passed**
- **Asian megaprojects launched**
- **More power to the Philippines**
- **Reactors reach a quarter century**

After two decades of false starts, wrong turns, and dead ends, the first steps toward widespread, institutionalized energy efficiency were finally taken in 1992.

The impetus, remarkably, was not any one ecological disaster or energy crisis, but rather two unrelated policy developments: the passage of comprehensive energy legislation by the U.S. Congress, and the Earth Summit meeting on global warming, in Rio de Janeiro last July.

Those developments and other factors point to a future emphasis on minimizing customer loads, largely through the use of efficient lights, motors, appliances, and other equipment. In developed countries, the loads themselves will increasingly be met with highly efficient generators (such as combined-cycle plants), renewable- and alternative-energy sources, and possibly even a new generation of nuclear reactors.

All told, conservation and tepid economies portend slow expansion of the North American and European generation and transmission equipment markets in the 1990s. Asia is another story. A thriving market there for heavy electric equipment is linked to brisker growth, in both economies and electrical demand. "The Pacific Rim has been where all the action is in the last five or six years," said a trade specialist at the U.S. Department of Commerce. "That will probably continue, unless the recession goes worldwide."

A number of giant contracts for power equipment, facilities, and engineering services were signed last year by Asian utilities. In anticipation of others to come, the world's largest heavy-equipment manufacturers formed several international alliances, to gain access to overseas markets or strengthen their product lines. In addition, a number of Asian nations announced significant additions to their nuclear programs—in sharp contrast with the state of nuclear power in the rest of the world.

LEGISLATION AT LAST. For U.S. utilities, the 1990s have already brought two pieces of blockbuster legislation. First came the Clean Air Act, amended in 1990 for the first time in 13 years. Then just last October, the House of Representatives and the Senate reconciled their energy bills, creating the nation's first comprehensive energy legislation in 15 years.

Glenn Zorpette Senior Associate Editor

Three years in the making, this act promises to affect all aspects of energy use in the United States, including power generation by conventional, nuclear, and alternative means; independent power production and regulation; transmission access; fuel production and regulation; energy conservation and efficiency; and research and development. The act will profoundly affect U.S. utilities well into the next century. And since the United States—which generates a quarter of the world's electricity—often sets broad trends in energy industries, the law's impact may well be felt by other advanced nations that find themselves grappling with similar issues.

The legislation has its origins in the Department of Energy's National Energy Strategy, to which Congress added provisions to encourage or mandate energy efficiency and conservation. The lack of such clauses was one of the major points of contention when the Department of Energy delivered the strategy to Congress in March 1991, after working on it for two years. Congress also eliminated a provision that would have permitted oil drilling in a vast wildlife refuge in Alaska.

Key provisions affecting utilities include: so-called "one-stop" nuclear licensing, in which construction and operating licensing would be consolidated, and emergency planning would be resolved *before* the issuance of the combined license; tax-free rebates for investments in efficiency; and the institution of permanent tax credits for solar, geothermal, and certain biomass plants.

Two pivotal provisions concern the 57-year-old Public Utility Holding Company Act (Puhca) and access to transmission lines. Puhca curtailed the spread of large utility holding companies in the United States, and it indirectly resulted in utilities' gaining full control over transmission and generation in their territories.

Under the new legislation, on the other hand, almost any organization may generate and sell electricity at the wholesale level. The Public Utility Regulatory Policies Act of 1978 had allowed the independent production of electricity, but only from renewable resources or from cogeneration.

The legislation will provide broader access to utility-built and -owned transmission lines by giving the Federal Energy Regulatory Commission (FERC) authority to order a utility to transmit power for some other organization—a municipal utility or an independent power producer, for example. The rates that the utility can charge for the service will be "just and reasonable" ones determined by FERC.

"FERC can affirmatively order transmission, and that's revolutionary," said Leon Lowery, legislative director for Environmental Action Inc., Takoma Park, Md. "It's the single biggest issue in the history of the electric utility industry" after, perhaps, nuclear power, he said. Nonutility generators and their customers have long maintained that without mandated access, utilities can restrict the operations of competing generators by refusing to transmit their power or by charging exorbitant fees to do so.

The legislation also addresses one of the thorniest issues in some time: that of "self-dealing," whereby a utility sets up a quasi-independent but affiliated electricity-generating company—not subject to the same regulations as the utility—and then buys power preferentially from that company. Such self-dealing was fairly common during the 1980s.

In Michigan, for example, the state's Public Service Commission found that Consumers Power bought electricity from its affiliated, 1300-MW Midland Cogeneration Venture to the exclusion of other independent power producers. In 1989 the California Public Utilities Commission charged that between 1984 and 1987, Southern California Edison Co. bought power from two affiliated cogenerators at inflated rates, and passed the costs on to ratepayers.

Under the new law, self-dealing will be Federally prohibited, unless the local state regulatory agency chooses to permit it in

HIGHLIGHTS

Success: U.S. Congress finally passes the country's most comprehensive energy legislation in 15 years.

Shortfall: Accident at a Japanese nuclear plant forces the second activation of an emergency core-cooling system—19 months after the first.

Notable: China, Egypt, Syria, and Iran arrange to buy nuclear reactors; Korea buys Canadian heavy-water reactors.

Newsmaker: Gordon Wu, the Hong Kong financier, was behind a number of blockbuster power projects in energy-hungry Asia.

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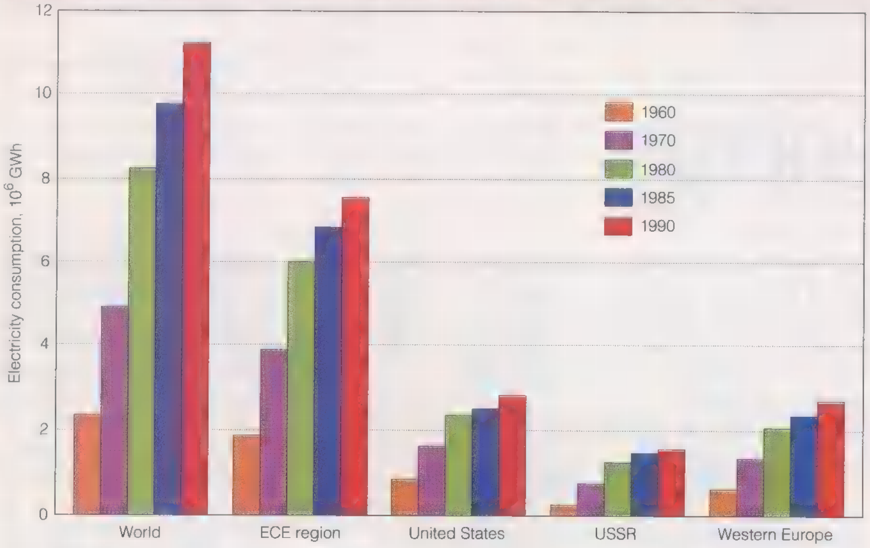
World and regional consumption of electricity, 1960–90



ECE = United Nations Economic Commission for Europe

Source: *Annual Bulletin of Electric Energy Statistics for Europe, 1992* (United Nations)

Increases in the use of electric energy have declined over the last decade, particularly in the ECE region. The ECE includes all of Europe, North America, and the former U.S.S.R.

specific instances. Such permission will be contingent upon: the state having sufficient access to the books and records involved to monitor the arrangement; the compliance of the contract with all state laws; and the contract being in the public's interest (however the state defines that interest).

A substantial R&D component in the legislation will foster work on clean-coal technologies, nuclear fusion, energy conservation, advanced nuclear reactor designs, electric vehicles, and the possible health effects of electric and magnetic fields.

The European Community (EC) has also been working on an energy charter, but one more focused on fostering competition in the European energy market [''Complex regulations. . .,'' opposite page, and ''Power and energy,'' *IEEE Spectrum*, January 1992, pp. 49–51]. The ambitious undertaking was stalled by disagreements among EC members, even before the monetary crisis cast doubt upon the pace, and even the principles, of market unification. The countries could not agree on whether foreign energy investors would be treated the same as domestic ones, or even on the timetable and specifics of transitioning to the charter.

Another contentious issue—how to modify energy policy to take account of the Rio de Janeiro summit—was perhaps understandable, given the summit's moot treaty. It calls upon utilities and industries to make their ''best efforts'' to reduce greenhouse gases, particularly CO_2, of which utilities are the largest producers. But no specific reductions, or timetables to put them into effect, were agreed upon.

ASIAN GROWTH. Even if U.S and European utilities do adhere strictly to efficiency and environmental standards, it may not do enough to limit global emissions of greenhouse gases and other pollutants. Much of the developing world, still struggling to electrify, cannot afford the cleaner-burning combustion technologies becoming available from Western and Japanese companies. In many Asian countries, where economic and electrical-demand growth are stronger than in the West, environmental standards are often less rigorous—70 percent of China's generating capacity is coal-fired.

This last point gains in significance from the galloping growth in parts of Asia. Whereas electrical demand is rising at roughly 2 percent per year in many Western nations, demand growth of 5–10 percent is the norm in Asia, and 15–16 percent is not unheard of. According to one estimate, by Munich-based Siemens AG, the Asian market—excluding India—will account for 37 percent of the world's new generating capacity between now and 2000. The bill for these capacity additions will total US $500 billion, according to the Asian Development Bank, Manila, the Philippines. In contrast, the European market for heavy electrical equipment is estimated at $50.6 billion this year, and will decline to $26.4 billion in 2000. (These estimates, by the London-based market research firm Frost & Sullivan International, include both generation *and* transmission equipment.)

Among the blockbuster contracts awarded last year: $1.9 billion for two 610-MW coal-fired units in East Java, Indonesia, to be built by a consortium led by Mission Energy Co., Irvine, Calif., and including General Electric Co., Fairfield, Conn., Mitsui in Tokyo, and Batu Hitam Perkasa of Indonesia; $648 million for a 1180-MW combined-cycle plant in Indonesia, to be built by a consortium of the Swedish-Swiss ABB Ltd., based in Zurich, Asea Brown Boveri Corp., Osaka, and the Japanese Marubeni Corp., Osaka; and $305 million for a 650-MW combined-cycle power plant in India, to be built by the same consortium, with the addition of Kawasaki Heavy Industries.

As usual, many western observers believe the real gold mine could be China. If so, the motherlode is Guangdong, a province of 63 million in the southeast, north of Hong Kong. The province has managed remarkable economic growth—27 percent in 1991—with a generating capacity that meets only 70 percent of demand. Aware that further growth depends on boosting generation, the Government plans to add 6000 MW by 1995. Present capacity is about 10 000 MW.

''Given the economic boom in Guangdong and the scale of its new power plant strategies, Guangdong must be one of the world's biggest potential markets for power generation equipment/systems,'' concluded a U.S. Department of Commerce report from the U.S. consulate in Guangzhou.

Among the contracts awarded last year was one worth about $1 billion, for two 655-MW coal-fired units at a plant that will be called Shajiao C. Lead contractor GEC-Alsthom NV, Amsterdam, will be responsible for design and engineering of the plant, 100 km south of Guangzhou. ABB-Combustion Engineering Systems, Windsor, Conn., will build the plant's boiler islands.

The Government is expected to invite bids soon for another huge project, Zhuhai Sez, which will eventually encompass four 660-MW units. At least three other generation projects will be built around pairs of smaller (300-MW) Chinese boiler/turbine systems, and one, called Shantou Sez, may use Russian equipment and technology.

China's hunger for power has led to the alarming proposal to dam the Yangtze River at Three Gorges, one of the world's great natural wonders. In early March, the Chinese parliament approved the project, which could cost more than $10 billion and produce up to 17 000 MW, or about 84 million MWh a year, when complete. Flooding caused by the dam, however, would displace more than a million people and inundate more than 20 000 hectares of land, 950 km of roadway, and hundreds of factories, mines, and power plants. The project is unlikely to get under way before the next century, according to some observers.

POWER SHORTAGE. Inadequate generating capacity is also constraining economic growth in the Philippines. A predicted rise of roughly 3 percent this year was held below 2 percent by inadequate capacity, according to a report in London's *Financial Times*. Electricity rationing and brownouts have become common all over the Philippines, including metropolitan Manila.

To rectify the situation, the state-run National Power Corp. (Napocor), in Manila, solicited proposals for private power plants to supply Luzon and Mindanao and to be completed by September 1993. A longer-term plan was also unveiled, for 900 MW of

capacity, also in Luzon, by 1997.

Behind the spate of big power projects in the Philippines, China, and elsewhere is the surging popularity of two financing mechanisms, known as Build-Operate-Transfer (BOT) and Build-Operate-Own (BOO). Most of the Asian projects described above are BOT affairs, under which a plant is built by a private company or consortium, which operates it for a decade, say, charging a previously agreed-upon rate for the plant's output. Then the plant is either given to the host government or sold at some contractually specified price. (BOO is like BOT, except the private organization retains ownership.) BOT was popularized in China by Gordon Wu, the Hong Kong financier behind several large Asian power projects.

"That's the name of the game now," said a Commerce Department official. "So many of the developing countries have resources but not financing. So if a consortium can bring some money to the table and be guaranteed the right to sell whatever they produce to the grid, they have a chance to get something built that they otherwise wouldn't."

Business opportunities of this magnitude have prompted several business alliances. Last year, General Electric and Toshiba Corp., Tokyo, announced they would join forces to produce large gas turbines. The two will also jointly seek gas-turbine orders in China, the Philippines, India, and elsewhere in Asia. GE already had links to Hitachi and GEC-Alsthom, the latter for European projects.

To better compete with GE, Westinghouse Electric Corp., Pittsburgh, agreed to a 15-year cooperative venture with Rolls-Royce PLC, London. For Westinghouse, the deal means access to Rolls-Royce's state-of-the-art turbine technology, developed for jet engines. For Rolls-Royce, the partnership opens up international power-generation markets. Westinghouse already had agreements with Mitsubishi and Fiat-Avio of Italy, so the addition of Rolls-Royce actually completes a foursome.

NUCLEAR SALES. Asia's ambitious power plans differ from those in the West in at least one key area: nuclear energy is a large, and growing, component. Last September, for assistance in selecting equipment makers, builders, and engineers for its long-planned Dragon Gate nuclear plant, the Taiwan Power Co., Taipei, awarded a $4 million con-

EXPERT OPINION: Complex regulations will be needed to head off unfair competition

JACQUES CLADÉ

The year 1992 heard continued debate and discussion among electric utilities and their Governmental regulators and overseers on the century-old subject: how most efficiently and cost-effectively to organize the generation, transmission, and distribution of electricity.

The Commission of the European Community, for example, has drawn up a draft directive for setting up a single, pan-European market for electricity. This directive will recommend third-party access to transmission lines, enabling major consumers to choose their electricity suppliers and so opening the way to competition.

An analysis of this proposal by European electric utilities noted, however, that generating facilities are capital-intensive investments vital to the communities they serve. With their long construction and service lives, they require long-term planning by organizations having a sense of responsibility for the continuity of low-cost service. Normal market forces are much too short-term and unpredictable to ensure this continuity.

In any case, direct contracts between consumers and producers will be feasible only for the larger customers, which alone would have the clout to work out deals and rates to their advantage. A ramification of this situation could be the bullying by these major customers of domestic consumers or small and medium-sized industrial customers. In France we call this "rente de situation" (situation rent), meaning a windfall due to an artificial situation rather than a sound economic purpose. To overcome all of these drawbacks, complex regulations will be needed, adapted to the diversity of institutional and national situations of the many electric utilities in the European Community.

In brief, the anticipated advantages of greater competition, such as improved efficiency and customer service, may not sufficiently offset the potential problems, like overuse of finite transmission resources, and the cumbersome regulations and bureaucracy needed to run competition on a large or international scale. Thus the draft directive has been rejected by most of the member states concerned.

The debate has nonetheless enlarged our knowledge of the economic and technical issues underpinning the proposal. Analyses of these issues are being done, and they are similar to others done elsewhere—particularly in the United States, which has also been seeking ways to foster greater competition in its electricity markets.

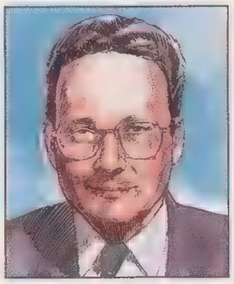
The general theme of competition versus cooperation was, moreover, the topic of a plenary session of the International Conference on Large High Voltage Electric Systems (known by its French acronym, Cigré) last September in Paris. The measures taken by some countries to foster competition within their electric utility structures were presented. Most of the attendees, however, expressed their conviction that coordination remains a basic requirement, for technical and financial reasons.

During this Cigré plenary session, there was a debate on the future of gas-fired electrical generation, from natural gas or coal gasification. This seems attractive to some utilities in view of present natural gas prices, and may lead to the further development of such gas-based generation techniques as coal gasification and combined cycle, which must be followed closely by utilities.

Of course, greater demand for gas may well raise prices. Thus nuclear energy is being considered again by some utilities. With public opposition still strong in some quarters, the utilities must spread the word that nuclear power is nonpolluting and can be very safe when the plant manufacturer, owner, and operator have the necessary experience and skills, and when safety officials are firm, reasonable, and independent.

Also of public concern are the possible physiological effects of electric and magnetic fields, such as those surrounding transmission and distribution lines. Medical studies have been going on now for over two decades, showing that such effects, if any, are subtle and difficult to detect. On the other hand, there is nothing subtle about the aesthetic "pollution" of unsightly overhead lines. It is up to utilities to take this into account and to work with communities on this issue, to bury lines whenever practical, or provide compensation to those adversely affected by the erection of an unavoidable overhead line, particularly one at extremely high voltage.

This does not mean, of course, that utilities should start taking the blame for all the ills attributed to them. After all, the significance of electricity in modern society can hardly be overestimated. And with hard work and good customer relations, there should be no difficulties that cannot be overcome.



'The anticipated advantages of greater competition, such as improved efficiency and customer service, may not sufficiently offset the potential problems, like overuse of finite transmission resources.'

Jacques Cladé (F) heads the central department for contracts at Electricité de France. He previously managed the system studies department and the R&D of electric equipment, and has been deputy director of the company's international division. He was vice president, and is an emeritus member, of the Société des Electriciens et Electroniciens (SEE), and chaired the System Planning and Development Committee of the International Conference on Large High Voltage Electric Systems (Cigré).

tract to a consortium of Ebasco Services, Belgatom, and CTCI, a quasi-official Taiwanese engineering firm under the Ministry of Transportation and Communications. Four other consortia are competing for contracts totaling $6 billion or more to supply and build the plant's units 7 and 8, each between 1000 and 1300 MW.

Some half-dozen reactors are also planned or under construction in China, whose premier, Li Peng, was trained in Moscow as an electrical engineer and later held high-level electrification posts. A milestone of sorts was reached early in 1992, when a 300-MW experimental reactor at Qinshan, near Shanghai, the country's first and based mostly on indigenous technology, finally went into operation after 20 years in construction. Next October, one of the two French-built 900-MW reactors at China's first commercial nuclear plant, Daya Bay, is scheduled to go into operation.

In Japan, meanwhile, an accident at a reactor in Fukushima led to a second activation of an emergency core-cooling system, only 19 months after the first such event. Conflicting reports alternately blamed operator error and water-pump malfunction. The episode seems not to have set back plans to add some 40 million kilowatts of nuclear generation by fiscal 2010, despite persistent public uneasiness with nuclear power in Japan.

The Korea Electric Power Corp., which already operates nine nuclear plants, announced last September that it would pay nearly $800 million for two 700-MW reactors from Atomic Energy of Canada Ltd. The Toronto-based company produces a unique pressurized heavy-water reactor (PHWR), in which heavy water cools and also moderates the nuclear reaction to some extent. The fuel is natural (unenriched) uranium, which had made the reactor attractive to developing countries unwilling to depend on developed countries for fuel. Past buyers of these reactors include Pakistan and India, which apparently used an older PHWR model to produce nuclear material for weapons.

Egypt and Syria also arranged to acquire small reactors. The Egyptian Government announced it had contracted with the Argentinian company Investigaciones Aplicadas for a 22-MW research reactor. It will replace an aging Soviet one that will be dismantled.

After agreeing to sign the nuclear nonproliferation treaty and submit to the safeguards of the International Atomic Energy Agency (IAEA), Syria managed to buy two small reactors from China. One of them is a 24-MW research reactor.

Iran also made moves toward the nuclear arena—whether to begin alleviating an acute shortage of capacity or as the first steps in a weapons program, no one can say. In September, various news organizations disclosed Russia's intent to sell two 440-MW pressurized-water reactors to Iran, as part of a fire-sale of systems and equipment intended to raise capital. The Russians countered that the reactors would be under safeguards of the Vienna-based IAEA.

Of course, Iraq's nuclear program, which came within a few years of producing a bomb, began modestly with one Soviet and two French reactors, all ostensibly for peaceful purposes. All were also under IAEA safeguards.

DECOMMISSIONING REACTORS. Outside Asia, it was a discouraging year for the nuclear industry. In the United States, economics or referendums forced plans to close three reactors, one of them just 16 years old. "When you see a 16-year-old, 1100-MW plant being closed, you have to ask yourself, is something going on here? And I think the answer is yes," said Scott Fenn, director of the Environmental Information Service for the Investor Responsibility Research Service in Washington, D.C. "Operating costs for nuclear plants now exceed those for coal plants on an average basis," Fenn explained.

The three U.S. plants slated for closure are the Yankee Rowe plant in Rowe, Mass., operated by Yankee Atomic Electric Co.; the 16-year-old Trojan plant in Prescott, Ore., operated by the Portland General Electric Co.; and San Onofre unit 1, owned by Southern California Edison Co. and San Diego Gas & Electric Co. The plants had steam generators in need of repair or refurbishment, or reactor vessels embrittled by years of bombardment by nuclear particles. With repairs at each plant estimated at between $100 million and $200 million, decommissioning (in roughly the same price range) seemed the better option.

Aging nuclear plants were also at issue in Great Britain, where five reactors are more than 25 years old. In August, the oldest of all, at Bradwell in Essex, won approval from Britain's Nuclear Installations Inspectorate to run for 10 more years.

Reactors to come also received some attention. In late August, General Electric's simplified boiling-water reactor (SBWR) joined several other reactor designs submitted to the U.S. Nuclear Regulatory Commission for possible certification. The reactors will be less complex, and some will have so-called passive safety features that depend on natural forces like gravity for operation, rather than pumps, valves, and other electromechanical devices.

SOVIET FALLOUT. Concern over decaying Soviet power reactors, which were built to safety standards far less rigorous than those in the West, was heightened in 1992. In early July, the Russian deputy atomic energy minister, Viktor Sidorenko, listed four nuclear incidents since 1991 classified at level three on the IAEA's seven-level scale describing the severity of mishaps. A three indicates a "serious fault involving loss of protection or heavy pollution or radiation of personnel."

Of most concern are the graphite-moderated RBMK reactors of Chernobyl infamy; one of the level-three accidents was at an RBMK at Sosnovyy Bor, near St. Petersburg, which suffered a radiation leak last March. In early December, news reports indicated that safety systems had been shut off three times at a Ukrainian reactor, possibly as part of an attempt to boost power. Despite the problems, meetings of the G7 nations in July and of the Organization for Economic Cooperation and Development (OECD) in Brussels in September produced no unified emergency plan or fund for coping with the crisis. Instead, some $600 million in aid has been pledged piecemeal by OECD nations to former Soviet republics and eastern European nations.

Another nuclear legacy of the USSR's breakup is fuel—hundreds of metric tons of it, at bargain prices. The bomb-grade material, with at least 93 percent highly fissile U-235, would have to be diluted with U-238 to produce reactor-grade fuel, which has just a few percent U-235. The diluted material would be useless for weapons, but could fuel all the world's reactors for decades. However, U.S. uranium companies and the Commerce Department saw the plan as dumping of the material on the U.S. market at unfairly low prices.

A BIG WIND. With generating options such as nuclear power seemingly out of reach for utilities in the United States and some other countries, it was heartening to see another source near wider use. Wind power, which enjoyed a heavily subsidized spurt in the 1970s, seemed again on the verge of establishing itself, this time on its own merits.

The difference this time is windmills that are much more efficient and thus cost-effective, thanks to computer control and adjustable blades of strong, lightweight materials. Major projects announced last year included a 250-MW "farm" of 600 windmills at Iowa-Illinois Gas & Electric Co. in Davenport, Iowa; a 50-MW wind farm for the Sacramento Municipal Utility District; a 50-MW farm for a group of four utilities in the northwestern United States; a 31-MW farm—Europe's largest—to be built near Llandinam, Powys, in Wales; and a 25-MW project in the Netherlands.

Though clean and renewable, wind power is not unobtrusive. Asked Fenn of the Investor Responsibility Research Center, "Are people really going to want to see fleets of windmills on every scenic mountain pass in this country?"

Elsewhere on the R&D front, a six-year cooperative effort to design an International Thermonuclear Experimental Reactor was launched by representatives of the European Community (EC), Japan, Russia, and the United States. Ideally, the fusion reactor designed would prove the technology's feasibility for generating electricity. If successful, the teams will consider building it.

The design project will be directed by an EC energy-research official, who will coordinate and integrate the efforts of design teams from the four participants. Three sites of activity will be San Diego, Calif.; Garching, near Munich; and Naka, Japan. ✚

Consumer electronics

- **_Adopted: a U.S. ghost-canceling reference signal_**
- **_The FCC outlines a U.S. path to HDTV_**
- **_Digital audio broadcasting is going global_**
- **_Consumers warm to home theater_**

The arrival of new consumer electronic products has been speeded by technical innovations and regulatory actions. For example, a U.S. ghost-canceling reference signal was adopted by the Advanced Television Systems Committee (ATSC) in Washington, D.C. It promises to eliminate multipath distortions from future home TV receivers that incorporate special digital signal-processing circuits and filters.

Also in the United States, the Federal Communications Commission (FCC) in Washington, D.C., anticipating the selection of a high-definition television (HDTV) transmission standard by the end of 1993, outlined a broad regulatory framework for the U.S. transition to HDTV. That schedule calls for a total phase-out of existing National Television System Committee (NTSC) broadcast transmissions and total changeover to HDTV by the year 2008, a move that would obsolete all current-design TV receivers. Interestingly, this proposal does not impact cable television, which can continue providing the current format of television as long as subscribers demonstrate interest.

Digital audio broadcasting, which will bring consumers at home and in their cars compact-disc–like audio quality, is still being actively investigated worldwide. And home theater continues as the focus of strong marketing efforts to sell surround-sound audio and large-screen video equipment.

GONE GHOSTS. Efforts begun in 1989 by ATSC, at the request of the National Association of Broadcasters (NAB), Washington, D.C., culminated in August in the ATSC's adoption of a ghost-canceling reference (GCR) signal developed by Philips Laboratories, Briarcliff Manor, N.Y.

Invented by David Koo, a Philips staff member, the GCR signal is designed to be embedded in the vertical blanking interval of the currently transmitted NTSC video signal. The GCR signal [Fig. 1] undergoes the same distortions as the video signal. Television receivers equipped with special digital-signal processors compare the received GCR signal with an unimpaired stored GCR waveform. The receiver circuits then automatically configure one or more compensatory filters to correct for the distortions introduced in the transmission path.

Ronald K. Jurgen Contributing Editor

As Koo explained in U.S. Patent 5 121 211, dated June 9, 1992, the fact that the GCR signal is used to characterize the frequency or impulse response of the channel (including the transmitter and receiver, as well as the transmission path) means that the frequency spectrum of the GCR signal must represent all frequencies contained in the 4.3-MHz pass band of the NTSC signal and must be as flat as possible in that band. Koo said further, "If there is a null in the spectrum of the GCR signal, where the spectrum is near zero over some frequency interval," then the channel will require compensation over that interval.

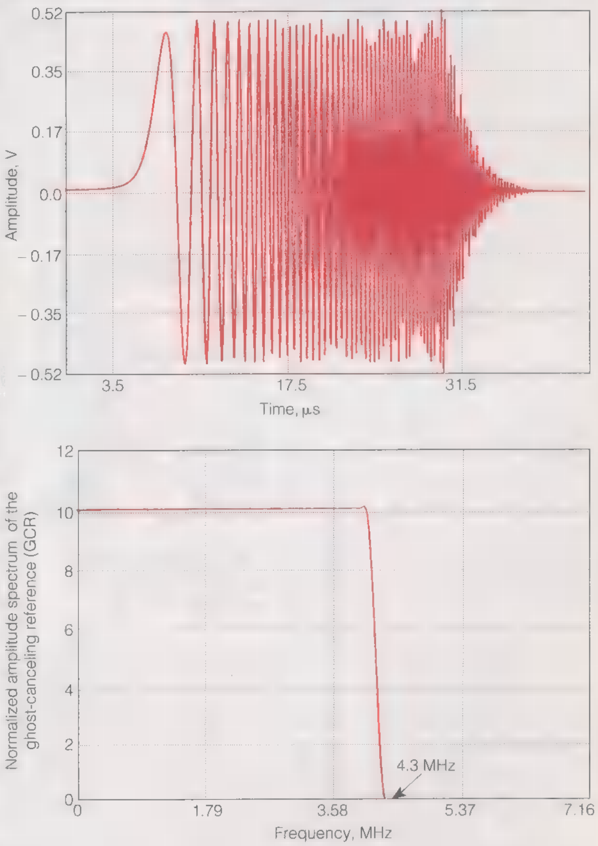
The Philips GCR signal was selected after extensive testing of competing systems from four other industry groups. ATSC, in announcing the selection of the Philips system, said it was the most effective. The committee predicted that both broadcasters and cable operators would embrace the new technology and that receiving equipment incorporating ghost-canceling circuits would "soon be available." Cable operators will likely use professional models installed at the cable headend to give all subscribers the benefit of ghost reduction, even those with older receivers.

Also in August, ATSC filed a Petition for Rule Making with the FCC, seeking the use of line 19 of the vertical blanking interval for the optional, but exclusive, use of the GCR signal. Line 19 has been reserved by the FCC for the vertical interval reference (VIR) signal once used to improve home color television reception but not used in receiving equipment manufactured since 1985. Other color improvements developed in prior years lessened the need to rely on VIR circuits.

A PATH TO HDTV. Even though the FCC has not yet selected an HDTV transmission system for the United States, the commission adopted in September a broad regulatory framework for introducing HDTV. The FCC said then that companies owning NTSC television stations would be given a second channel on which they would broadcast HDTV programs. The two-channel setup would be in use for 15 years.

After 15 years, the FCC said, it would require the broadcasters to give up one channel so that it could be used for some other purpose. At that point, since only HDTV programming would be broadcast, consumers would either have to purchase HDTV sets or buy an adaptor to convert HDTV programming for viewing on NTSC receivers.

Earlier, in June, ATSC filed with the FCC information on proposed industry actions to



[1] The Philips GCR signal [top] has a high-energy level with peaks evenly distributed in time. The signal [bottom] has a flat amplitude spectrum in the band of interest.

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fully document the selected HDTV standard. Once it is selected, ATSC said, several standards-setting organizations, including the IEEE, should begin documenting a wide range of standards for the equipment to be used to broadcast the HDTV signals. Those standards would include RF characteristics, source coding of video and audio, and program-related services.

DIGITAL AUDIO BROADCASTING. In yet another example of the rapid application of data compression techniques, broadcasters worldwide are preparing for digital audio broadcasting (DAB). It would enable—if Government regulations permit—AM and FM radio stations and satellite broadcasters to transmit sound with nearly the same quality as compact audio discs.

At the First International Symposium on Digital Audio Broadcasting held in Montreux, Switzerland, June 8–9, strategies for the global introduction of DAB were discussed. Earlier, in Torremolinos, Spain, the 1992 World Administrative Radio Conference allocated radio-frequency spectrum for satellite DAB. A bandwidth of 40 MHz in the region of 1.5 GHz (1.452–1.492 GHz) was made available in all regions of the world, but many countries took exception to that allocation. For example, 15 countries selected 2.5 GHz, the United States took 2.3 GHz, several countries took both 1.5 GHz and 2.5 GHz, and India took 1.5, 2.3, and 2.5 GHz. And in addition, for terrestrial DAB, many proposals have been made worldwide.

In Montreux, Richard C. Kirby, director, International Radio Consultative Committee, International Telecommunication Union, located in Geneva, Switzerland, summarized the satellite developments. "Europe's pioneering of DAB makes credible a tentative target date of 1998 to imple-

EXPERT OPINION: Consumers seek easy-to-use products

MICHAEL A. ISNARDI

Despite the harsh economy, consumers continued to reel under a barrage of innovative high-end video and audio products. They could see many of them in Chicago in May at the International Consumer Electronics Show, open for the first time to the public. Most curiosity was aroused by products that offered new features in easy-to-use formats. Also of great interest were manufacturers' versions of living room theaters.

Consumers can expect to see a variety of new features in video products. Closed-caption decoders will be built into all TV sets with 13-inch-diagonal and larger screens distributed for sale after July 1993. Wide-screen TV sets from Thomson/RCA, Indianapolis, Ind., will be available along with camcorders that have a wide-screeen "letterbox" mode of operation. High-end TV sets will have built-in deghosters taking advantage of the recently standardized U.S. ghost-canceling reference signal to be broadcast with National Television System Committee signals. Camcorders will boast image stabilization and digital zoom. VCR programming will be simplified by integrated VCR Plus+, voice-command programming, and products like Panasonic's LCD Program Director, TV/VCR combinations, and dual-deck VCRs that provide simplified playback, recording, and dubbing of videotapes.

'We will have more control over the products we use.'

Work continues with the Electronic Industries Association, Washington, D.C., on the standardization of extended data services for television, an extension of the closed-caption data format. These services, once approved, will enable consumers to extract useful information about a TV program such as name, network, rating, and type as well as time information, so they can set their VCR clocks automatically.

On the horizon lies a new generation of consumer products that will appear with the adoption of the next U.S. television transmission standard. Testing of the six advanced TV systems was completed in October at the Advanced Television Test Center in Alexandria, Va. One of the four digital high-definition television (HDTV) systems is expected to be chosen. Although Europe and Japan have been working extensively on analog HDTV transmission systems, several countries have recently announced plans to develop digital HDTV systems as well.

DirecTv is another massive U.S. digital TV effort. Sponsored by Hughes Communications Inc., El Segundo, Calif., DirecTv will beam 100 channels of entertainment programming to U.S. TV sets by direct broadcast satellite in early 1994. The home receiving system, consisting of a small antenna and a compact digital decoder box with impulse-pay-per-view capability, will be manufactured and distributed under the RCA brand name. Hubbard Broadcasting Corp.'s DBS venture, U.S. Satellite Broadcasting, is also expected to initiate a DBS service from the same Hughes satellite.

In audio electronics, consumers will be free to choose from three digital recording formats. Digital audio tape (DAT), while popular with professionals, has not appealed to consumers. This may be due to its lack of random access that consumers take for granted with compact discs (CDs). Philips' new Digital Compact Cassette (DCC) shares this drawback, but a value-added feature on DCC machines is that they can play existing analog audio cassettes.

Another digital audio format, Sony's MiniDisc, features random-access playback and records as well. The first units available are portables. Unlike DAT, which preserves the quality of uncompressed audio, both DCC and MiniDisc use digital audio compression.

The pace is quickening on the digital audio broadcasting (DAB) front in the United States. Some cable systems are already offering this service. The EIA has received over 10 proposals for terrestrial DAB systems and testing is expected to start this year.

New digital communications products introduced last year included cordless phones that offer static-free and secure communications with an extended range compared with existing analog phones. AT&T Co.'s video phone is making a comeback with digital audio and video compression and state-of-the-art modem technology. Squeezing audio and video to fit over standard phone lines is an amazing feat, but the ultimate fate of the video phone lies, once again, with the consumer.

Automated features are adding more value to home products. Smart appliances turn themselves on and off automatically. Motion- or photo-sensitive lights save energy and provide security. Central command units control small appliances remotely. And the EIA CE Bus committee has completed a communications framework that will provide a standardized way of controlling and monitoring home appliances.

Interactive products continue to vie for consumer interest. Video game systems have improved as faster microprocessors and 16-bit graphics provide realism for both skill- and learning-based games. Philips' Compact Disc-Interactive (CD-I) even allows the viewer to "wander" through large amounts of information stored on CD ROMs. For the first time, the viewer is in control of viewing. Over 100 interactive programs are available, ranging from games and sports to reference and self-enrichment. CD-I also plays Kodak's new Photo CDs. With CD-I and Photo CD technology, families can explore the treasures of the Smithsonian and enjoy the photos of their last vacation on their TV sets.

Interactivity could become an accepted way of culling through the vast amounts of multimedia that confront us daily. The way we learn and entertain ourselves in the future is the topic of serious research. While no one can predict precisely what products will be available to consumers 10 years from now, future trends are clear. We will have more control over the products we use, and the products will "learn" our preferences in an attempt to be more useful.

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ment a four-satellite highly elliptical orbit system (HEO) under study by the European Space Agency," he reported. "We might see a hybrid terrestrial/satellite DAB before the end of the century."

Many countries worldwide—33 in all—have said they will delay the allocation of 1.5 GHz. John D. Abel, NAB's executive vice president, spoke of developments in North and South America at the Montreux conference. Cuba, Colombia, Ecuador, and Panama, he said, have allocated DAB as a secondary service in L-Band (1200–1400 MHz) until the year 2007. Canada and Mexico, Abel reported, are poised "to proceed with plans to develop a terrestrial service at L-Band." Canada is preparing to build a permanent transmitting site for DAB in Toronto. And several European and Asian countries have similarly delayed the allocation of 1.5 GHz.

Satellite-delivered DAB also has its supporters. Satellite CD Radio, for one, Abel reported, has a petition before the FCC for a conditional construction permit to build two satellites at 2310–2340 MHz to provide 30 channels of DAB throughout the United States. The system's two satellites would each provide 30 identical channels at 50 W per channel, and receivers with 20-cm planar array antennas would be used to receive the satellite signals. In October, the FCC began proceedings to authorize DAB service in the United States at 2.310–2.360 GHz.

In the United States, terrestrial DAB proposals are for in-band systems—those that operate within the existing AM/FM radio band. In some systems, the DAB signal is placed on the broadcaster's existing frequency assignment; in others, an adjacent (unused) channel is used.

DAB system proposals are now being evaluated by the Electronic Industries Association (EIA), Washington, D.C., which has set up a Digital Audio Radio Subcommittee consisting of representatives of the semiconductor, manufacturing, satellite, and broadcast industries. Upon completion of the evaluation, the subcommittee plans to recommend a U.S. standard, tentatively scheduled for late 1993.

DAB proposals to EIA were coming in fast and furious late last year. Companies that had submitted statements of intent to produce DAB proponent systems to EIA include: Kintel Technologies, Mercury Digital Communications, Thomson Consumer Electronics, USA Digital Radio, Amati Communications, AT&T Bell Laboratories, MIT, LinCom, NASA, and Voice of America.

One on-channel supporter, Kintel Technologies Inc., San Jose, Calif., according to Abel, has proposed using a technique called power multiplexing to place the DAB signal underneath the FM signal on the same channel. USA Digital Radio—a Los Angeles-based consortium of CBS, Gannett, and Group W Radio (a Westinghouse subsidiary)—has demonstrated the ability to place a DAB signal 30 dB below the FM signal level and then extract, demodulate, and reproduce that signal. Mercury Digital Communications Inc., Monterey, Calif., Abel said, has proposed a system in which a version of orthogonal frequency-division multiplexing would generate eight-phase-shift-key modulated carriers—almost 200 of them—spaced 1 kHz apart.

HIGHLIGHTS

Success: Philips Laboratories' ghost-canceling reference signal was proposed by the Advanced Television Systems Committee as a U.S. standard.

Shortfall: Digital audio-tape recorders continued as a lackluster consumer product even as competition grew from MiniDiscs and Digital Compact Cassettes.

Notable: The first International Consumer Electronics Show ever open to the public attracted nearly 100 000 consumers, in addition to industry attendees, in Chicago in May.

Newsmakers: Zenith Electronics and AT&T, General Instrument, and the Advanced Television Research Consortium all conducted successful over-the-air field tests of their digital HDTV signals.

HOME THEATER PUSH. For a few years now, consumer electronics manufacturers have been campaigning to convince consumers that they would love the home theater experience. The equipment would include a large-screen television display, surround-sound audio gear, and associated VCRs, laserdisc players, and so forth.

At the 1992 International Consumer Electronics Show in Chicago in May, the campaign won a special display area at McCormick Place for component systems ranging in price from US $3446 to $37 585.

The $3446 system used components from Yamaha Electronics Corp., USA, Buena Park, Calif. It consisted of a Yamaha RX-V660 five-channel, audio-video receiver ($649), two NS-A325 front speakers ($599), a YST-SW100 self-powered woofer (included in the cost of the front speakers), an NS-C70 center-channel speaker ($129), two NS-A325 rear-channel speakers ($170), and an RCA F35050ST 35-inch-diagonal color television receiver ($1899).

The $37 585 system consisted of a Model Three Fosgate-Audionics surround-sound process controller ($2499), a Ran Corp. THX equalizer ($1299), three Marantz power amplifiers ($2097), three Fosgate-Audionics MC220 front speakers ($700), two Fosgate-Audionics SD 180 surround speakers ($1850), a Mil & Krel MX-5000 subwoofer ($2195), a Harmon Series II/DPM8 video projector ($11 995), and a Faroudja Laboratories line-doubler ($14 950).

Other exhibitors in Chicago also displayed home theater systems. Sharp Electronics Corp., Mahwah, N.J., for one, introduced the XV-H30U liquid-crystal display (LCD) projector ($3995) with what the company calls micro-optics lens technology. That technology makes the projector's thin-film-transistor LCD panels 50 percent brighter than Sharp's previous models. The XV-H30U has three 3-inch-diagonal LCD panels with 112 300 pixels per panel for a total of 336 960 picture elements.

SHORT TAKES. The competition for recordable digital audio heated up as Sony Corp., Tokyo, entered its MiniDisc in the Japanese and U.S. sweepstakes. A Walkman player-and-recorder ($750) and another playback-only model ($550) were scheduled to be launched in the United States in December. A car player is to show up in early 1993. Blank discs can record up to 60 minutes of music ($14) and prerecorded MiniDiscs were expected to sell at compact disc prices. Meanwhile, Philips Electronics NV, Eindhoven, the Netherlands, which had planned to begin marketing digital compact cassette players in September, delayed the launch of the units until October because of manufacturing problems.

In cable television (CATV), the U.S. House of Representatives and the U.S. Senate passed a bill to regulate CATV prices. The law calls for the FCC to set guidelines for prices for basic service. Companies that own cable systems and also produce programming would have to license products to such rivals as satellite services. Prices for converter boxes and remote control devices would also be regulated. Over-the-air stations and the networks could seek royalties from cable companies for retransmitting programming. And, in the future, consumers would be able to sign up for a single channel of special programming rather than having to take a package of channels. President Bush vetoed the bill, but Congress overrode the veto. Several court challenges to the constitutionality of some of the bill's provisions have been launched.

The bill directs the FCC to hold hearings on the compatibility of cable and consumer electronics. After a year of study, the FCC is to issue rules intended to improve the situation.

Gains were made in telecommunications as well. AT&T Co. introduced last January the Videophone 2500. It sends and receives full-color, limited-motion video over existing telephone lines for the same price as voice calls. The unit has a fold-up panel holding a 3.3-inch-diagonal LCD display and camera lens. It plugs into standard telephone and power outlets. Once a voice call is made, the users each touch the video key to activate the video call. The color video moves at 10 frames per second. Callers can ensure privacy by closing a shutter over the lens at any time. The Videophone came on the market in May at US $1499.

In September, MCI Communications Corp., Washington, D.C., announced plans to introduce in 1993 a video telephone for $750. It would be similar to the AT&T product. Both use signal compression techniques to enable the video signals to be carried on phone lines. ◆

Transportation

- ***Smart-highway plan goes to Congress***
- ***California leads in pushing electric cars***
- ***'Red October' dives in Kobe Bay***
- ***Nonstop air-traffic communications planned***

Gridlock on the ground, congestion over airports, and pollution in the air kept the pressure on the transportation industry to devise cleaner transit systems that move greater numbers of people, and to improve communications and guidance.

Political changes also made demands. Developments across the Atlantic are revising transportation in the European Community. The North American Free Trade Agreement is expected to ease the movement of goods across borders and let the United States and Canada invest in Mexican trucking companies.

And key elements of the 1990 Americans with Disabilities Act (ADA) became effective on Jan. 26, 1992. The sweeping ADA law mandates ease of access for the disabled to business places and public transportation. New systems and vehicles must accommodate the disabled within a few years, while older systems like New York City subways and Amtrak have 20 years to convert.

Meanwhile, the U.S. Census Bureau reported that the two best methods for cutting automobile pollution had declined during 1979–89: the proportion of workers using public transportation dropped from 6.4 to 5.3 percent, and the proportion of those in car pools fell from 19.7 to 13.4 percent. Low gas prices, suburban growth, and personal preference were cited.

SMART CARS, ROADS. The drive toward Intelligent Vehicle-Highway Systems (IVHS) was given an extra push by the Intermodal Surface Transportation and Efficiency Act (Istea), which was signed into U.S. law in December 1991. "For the first time, major legislation spelled out a role over the next six years for IVHS and made it a factor in surface transportation," said James Costantino, director of IVHS America, a nonprofit consortium based in Washington, D.C. He called Istea the most important transportation bill since the one chartering the interstate highway system in 1956. As the lead advisory committee to the U.S. Department of Transportation (DOT), IVHS America was tasked to produce a 20-year strategic plan for IVHS in the United States.

The hyphen between "vehicle" and "highway" symbolizes an important aspect of IVHS, for the concept involves "smart" systems in both vehicles and highways. More than 20 tests of operational systems are under way in the United States. Current Federal funding for IVHS is US $660 million spread over the next six years, about 10 percent of the estimated $6 billion that will be needed for all R&D and testing required for a nationwide system.

The IVHS strategic plan, delivered to Congress on June 29, was designed to guide DOT in setting goals and objectives, identifying key technical and policy challenges and solutions, suggesting appropriate public and private roles, outlining a course of action, and estimating funding needs.

Significantly, the report does not debate whether IVHS will happen. "There will be an IVHS program in the U.S., even without this plan," the Strategic Assessment chapter concludes. "However, an integrated national IVHS program is the best future strategy to achieve national, orderly, and organized IVHS deployment." Indeed, the diversity of programs under way lends some urgency to their integration: "Many participants in IVHS compete for resources and customers; many have objectives and constituencies at odds."

More cheerfully, the IVHS strategic plan sees opportunities in legal changes that are relaxing constraints on transportation projects and funding, and in "the availability of unused capacity in national laboratories and the defense industry [which] could be turned into an IVHS asset."

While the United States is shaping its plans for IVHS, two operational tests are under way in Europe. Prometheus (Programme for European Traffic System with Highest Efficiency and Unprecedented Safety) was started in 1988 by major European auto makers, high-tech firms, and academia. It is expected to result in commercial products such as electronic driver aids and vehicle-to-road communications in 1994. Drive (Dedicated Road Infrastructure for Vehicle Safety in Europe), sponsored by the European Commission, is in its second, $300 million phase, testing road infrastructure projects. It targets validation and test projects as well as common specifications.

In Japan, several projects are being sponsored by various government ministries. One is the Road/Automobile Communication System, whose roadside beacons aid driver navigation and communications. Japanese consumers spend $432 million annually on IVHS navigation systems.

'VOLTSWAGON' MARKET RECHARGES. More than 30 U.S. states are encouraging alternate-fuel vehicle (AFV) programs with fleet purchases, tax credits, and other initiatives. The strongest push comes from California (recently joined by New York and Massachusetts), which has mandated that 2 percent of new cars have zero emissions by 1998 (10 percent by 2003). The Northeast States for Coordinated Air Use Management, a region encompassing 40 percent of the light-vehicle market, is working to follow suit.

Effectively, the demand for zero emissions has revived work on electric vehicles, a market that has lain moribund since the 1970s. One early response is Green Motor Works, a car dealer that handles only electric vehicles. It opened in April in North Hollywood, Calif. Salesman Richard Hauser said the company replaces a car's internal combustion engine with electric systems. The conversions range from small neighborhood vehicles (around $11 000) to Porsche replicas ($36 000). Denmark provides the only "ground-up" electric vehicle sold at Green Motors.

Green Motor cars rely on lead-acid batteries and series-wound dc motors. Hauser declined to give sales numbers, saying only, "We have a showroom and a conversion bay and we're busy." It will also soon have competition. In 1993 Chrysler Corp. will sell up to 100 demonstration TEVans, electric models of the Plymouth Voyager. General Motors Corp. will demonstrate its Impact prototype, Sweden's Clean Air Transport Co. will export its LA301 car by mid-decade, and Japan plans to export electric vehicles to California by 1995.

HIGHLIGHTS

Success: Japan demonstrates a superconducting drive that could revolutionize shipping in a few decades.

Shortfalls: A bankrupt Pan Am is held liable for higher damages because it failed to protect flight 103.

Notable: Electrosource prepares to market advanced lead-acid batteries to power electric cars and other vehicles.

Newsworthy: Six-year funding and a 20-year plan for IVHS should help coordinate diverse public and private ventures.

Dave Dooling Contributing Editor

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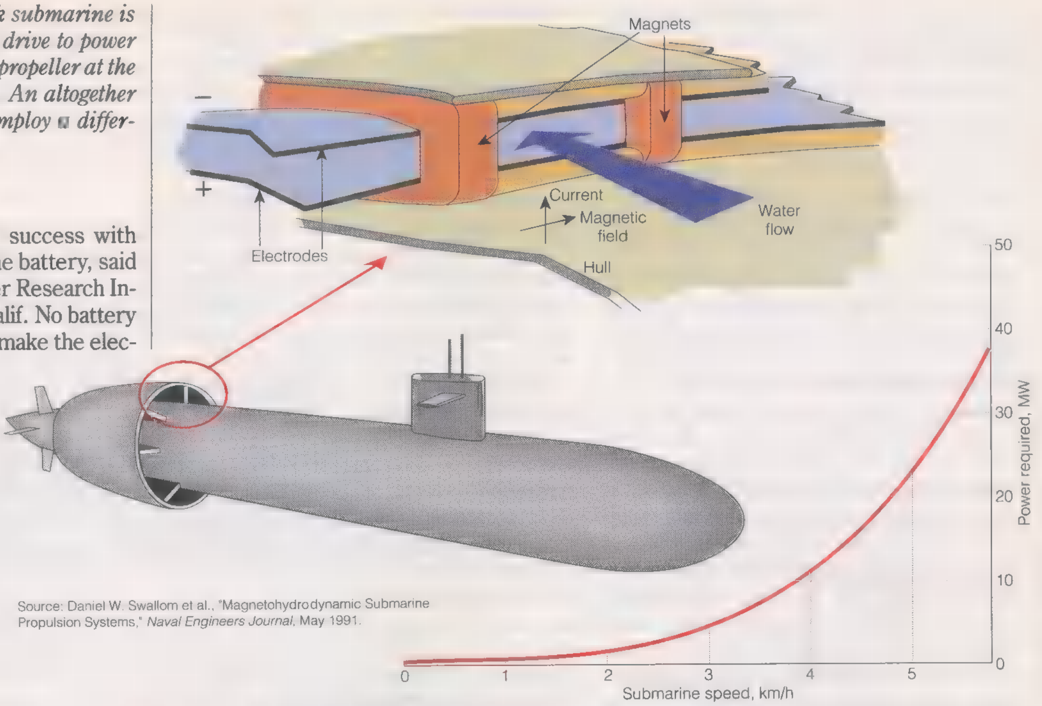
This Los Angeles–class attack submarine is shown refitted with an MHD drive to power it through the water without a propeller at the speeds indicated in the graph. An altogether new design probably would employ a different configuration.



Source: Daniel W. Swallom et al., "Magnetohydrodynamic Submarine Propulsion Systems," *Naval Engineers Journal*, May 1991.

The critical path to broad success with electric vehicles is through the battery, said Jack Guy of the Electric Power Research Institute (EPRI) in Palo Alto, Calif. No battery yet meets criteria that would make the electric car a desirable consumer vehicle, he said. To move the technology along, the U.S. Advanced Battery Consortium (USABC) was formed by the Big Three U.S. auto makers in 1990; they were joined in 1991 by EPRI and the U.S. Department of Energy, which together will supply half the program's $260 million over the next four years.

EXPERT OPINION: Growing worldwide reliance on electric transportation

HARVEY M. GLICKENSTEIN

High-speed rail, light- and heavy-rail traction, and trackless trolleys all played major roles in making 1992 an exciting year for transportation. The remainder of the century should see growing reliance on electric transportation around the world. Not only will new battery developments make electric automobiles economically feasible, but they will help electric buses, trackless trolleys, and light-rail vehicles without overhead wires. Rail is even being viewed as a part of the solution to crowded airways.

'Probably the biggest surprise is the upsurge in light rail and subway construction in heavily automobile-oriented southern California.'

Despite advanced work on magnetic levitation (maglev) rail, conventional rail is likely to be preferred for several years. High-speed rail projects advanced in Europe, North America, and Asia during the year. The United States soon will electrify the balance of the Northeast Corridor from New Haven to Boston. South Korea, Taiwan, and the United States proposed new systems, and Japan, France, and Germany planned to expand existing lines. Spain opened its first high-speed rail line, which operates at a maximum speed of 300 km/h. France continued to extend its domestic TGV network and planned to expand into England, Belgium, and Germany.

England added to its high-speed service to Scotland, although high-speed links between London and Folkestone (the British end of the cross-channel Chunnel) are being delayed. Sweden is providing high-speed service with its X2000 tilt-body rail cars (which the United States is testing in the Northeast Corridor). Japan is developing a new Shinkansen train to operate at up to 400 km/h. This will allow them to build the next Osaka-Tokyo high-speed line using conventional technology to achieve maglev speeds if maglev does not turn out to be economical.

Workers on various tunnel projects busily burrowed away. Construction continued on the Chunnel, but the opening date for train service between English and French terminals was pushed back to late 1993, and full utilization of the tunnel may slide to 1994 or later. Construction of new tunnels for electrified train operation and improvements to existing rail lines under the Alps were under way. Tunnels from Denmark to Sweden and Germany have been proposed, and these, with the Chunnel and the bridge-tunnel across the Great Belt separating most of Denmark from the mainland, will bring Europe even closer together. Plans were floated again for a Bering Straits tunnel that would link the Americas and Asia.

Light rail and heavy rapid transit also expanded. Europe, North and South America, Asia, and Australia saw new service. Probably the biggest surprise is the upsurge in light rail and subway construction in heavily automobile-oriented southern California.

Air pollution concerns revived trackless trolley operation in Toronto, and in Dayton, Ohio. Philadelphia and San Francisco are expanding their networks. Los Angeles is planning to install trackless trolleys and has advertised for a design consultant. Seattle has built a line for dual-mode rubber-tired vehicles that operate as trackless trolleys in a tunnel and as regular buses outside. Air pollution has also caused Switzerland and Austria to place strict limits on highway truck traffic through the Alps. Electrification of railroads to replace steam engines continues in India and China.

Finally, rail systems and other transportation in the United States have started implementing various provisions of the Americans with Disabilities Act (ADA). Under this law, regulations have been issued to improve access to all public accommodations for people with a variety of disabilities. In the transit area, wheelchair access is the immediate concern. Installation of new elevators, ramps, signs, and public address systems are also required under the ADA. In order to meet the wheelchair access provisions, Portland, Ore., has advertised for low-floor light-rail vehicles. Other transit authorities in North America are considering this option. In Europe, the first low-floor trams went into service in 1984 in Geneva. Germany, Belgium, and Italy now have low-floor vehicles in service in a number of cities. Switzerland is pioneering the low-floor intercity car; the first model was delivered in January 1992.

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Near-term batteries (that is, lead acid) were omitted from the program because GM considers they are the province of its Delco-Remy division, and EPRI's Technical Advisory Committee concluded that they will not perform as USABC requires. USABC is concentrating on mid- and long-term designs such as nickel-metal hydride and lithium-polymer. Nevertheless, the Advanced Lead-Acid Battery Consortium (AL-ABC), comprising U.S. and international firms like Volkswagen, BMW, and Mercedes, is advancing lead-acid battery technology as the best bet for use over the next few years.

WEAVING A BATTERY. Independently of that, Electrosource Inc., Austin, Texas, is moving ahead with its Horizon Battery Development Project. The Horizon battery can be made for one-fifth the cost of nickel cadmium, and looks promising for use in a range of electric vehicles in the mid-1990s. Rick Blanyer, an electrical engineer with Electrosource, said the firm is gearing up for commercialization in 1994, just 10 years after starting work on the battery. He said major auto makers in Japan and Europe and power transmission companies as well as Chrysler and Ford have expressed interest.

Horizon uses lead paste extruded onto glass fibers to produce an electrode with greater surface area, and hence higher capacity, than in conventional lead-acid batteries. (Electrosource holds seven design and manufacture patents.) That high capacity avoids a host of problems imposed on conventional lead-acid batteries by the need to harden the lead with antimony or calcium.

Borrowing from the textile industry, the lead-coated filament grids are made in a continuous weave that is relatively easy and cheap to produce. The glass-lead grids and glass separators become hygroscopic sponges that do not leak even when test batteries are cut apart, Blanyer said.

A 4-V prototype supplied to EPRI for testing during 1992 demonstrated 61 percent more power per kilogram than current lead-acid batteries (440 vs. 270 W/kg) and recharged two to five times faster (less than 5 hours vs. 9–24 hours) on a household outlet. With a "jolt" charger at a filling station, a 50 percent recharge is possible in 8 minutes and 100 percent in half an hour.

STEEL VS. MAGLEV. A study of high-speed intercity transport by the National Research Council, Washington, D.C., offered a good news/bad news rail review in late 1991. Everyone already knew the good news: high-speed ground transportation is feasible. The bad news is that it may cost $12.5 million per kilometer to install, and then will recoup its investment only in areas where it can draw 2 million to 17 million riders a year, depending on the system, NRC wrote.

In fact, Federal highway and airport trust funds may have to be tapped. "If the Federal Government wants to be serious about this, they're going to have to deal with the institutional issues, and so far, no one's done it," said study chairman Larry Dahms, executive director of the Metropolitan Transportation Commission, Oakland, Calif.

After examining everything from magnetically levitated railroads (maglev) to tiltrotor aircraft (which use small airports), the NRC decided that high-speed "steel wheel on steel rail" seemed the most feasible for routes 250–800 km long. Just a month later, the aerospace trade magazine *Aviation Week & Space Technology* supported using rail to feed long-haul air routes and unclog traffic jams at airports. It noted that Lufthansa German Airlines does just that at the Frankfurt airport with some 130 trains a day.

The same Istea law that boosts IVHS also gives local governments more latitude in developing such rail-air systems. "We are encouraging states to consider that option very seriously," said Mark Yachmetz, special assistant to the director of the Federal Railroad Administration (FRA) in Washington, D.C. By late fall, the FRA had taken advantage of Istea to select five rail corridors totaling more than 4000 km of lines, from southern Florida to the Pacific northwest, for upgrades to accommodate faster trains.

OTHER HIGH-SPEED RAIL. The main event in high-speed rail is a joint European venture (Siemens AG in Munich, Germany, and GEC Alsthom in Paris) and a Japanese consortium competing for a multibillion-dollar high-speed train in South Korea. France and Germany plan to build a high-speed rail system linking continental Europe's two largest economies. On July 14 the British Government announced it would sell British Rail's passenger and freight service to 30 or 40 franchises while retaining the tracks and infrastructure. Germany also planned to privatize after merging east and west German rail systems under a new company, Deutsche Bahnen AG.

The United States has three major high-speed rail projects in advanced development in Texas, New England, and Florida. The Texas Supertrain eventually will run along a triangular, 320-km/h route linking Dallas/Fort Worth, San Antonio, Austin, and Houston. The Texas High-Speed Rail Corp. must have raised $30 million in cash and $140 million in credit by the close of 1992 to seed financing for the $6.5 billion project. Significantly, the project will use France's electric Train à Grand Vitesse (TGV) system rather than a U.S. system.

The second project is the $400 million extension of 240-km/h electric rail along the New Haven–Boston corridor. Reverse signaling to accommodate the extension should be completed in time for construction to start in July. Also, early this year, Amtrak plans to seek proposals for high-speed trains that may use tilt-body suspension, as in Sweden's X2000, so that speeds on curves may be higher without bothering passengers. Amtrak brought an X2000 to the United States in November to test passenger response at 240 km/h through January on the relatively straight Washington–New York route. Later this year, the same tilt-body train will be put into service on the Washington–New Haven route.

At speeds up to 200 km/h, the X2000 compensates for centripetal force with an active tilt system and radial trucks that turn the wheels to match curves. Germany's Intercity Express (ICE) may be brought over for tests later this year, but it will be limited to 203 km/h by the physical tension limits of the overhead (catenary) wires that carry the electric current. The FRA was also evaluating the safety of TGV, ICE, and X2000, and acknowledged that U.S. regulations might have to change to keep pace with technology.

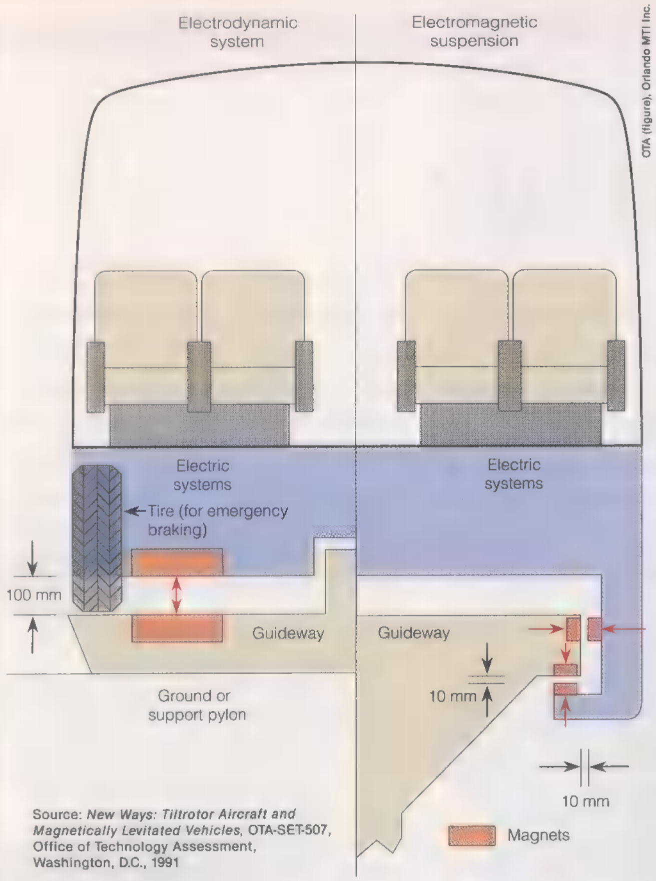
GETTING A LIFT. The third and best-known project is the 22-km link that Maglev Transit Inc., Orlando, Fla., is to demonstrate at Orlando International Airport. Construction is to start this year, with opening expected by June 1997. The $26 million National Maglev Initiative was to be completed and transmitted to Congress (which ordered it) in January 1993. The two-year assessment of the engineering, economic, environmental, and safety aspects of maglev should set national priorities in the field.

Los Angeles is examining the potential for electric trains to comply with the "zero emissions" standard, but greater promise may be found in diesel trains modified to burn liquefied natural gas (LNG). GM Corp., Detroit, Mich., and General Electric Co., Fairfield, Conn., are jointly developing such a demonstration vehicle. FRA also plans to spend $25 million over the next five years on projects to advance technologies such as suspension, signals, and constant-tension catenary systems.

"Buy American" protests prodded the Los Angeles County Transportation Commission into canceling a $122 million contract with Japan's Sumitomo Corp. It was for 41 light-rail cars. Although Morrison Knudsen Corp., San Francisco, had bid $5 million less, Sumitomo was judged technically and managerially superior. A new 15-car contract, which required that 60–75 percent of the rail cars be built in the United States, was re-awarded to Sumitomo in late 1992. The county also plans to build a $49 million rail car and bus factory, partly to employ laid-off aerospace workers. The cars will be used on light rail commuter lines that may span 650 km in two decades.

RED OCTOBER SAILS. Life imitated art (a bit) when Japan tested a ship propelled by magnetohydrodynamic (MHD) thrusters akin to the "caterpillar drive" used by the super-quiet submarine in the popular 1989 movie, *The Hunt for Red October.* In a half-hour test run on Kobe Bay, Yamato 1 (an ancient name for Japan as well as for a battleship), reached a top speed of about 11 km/h (6.2 knots).

Although MHD propulsion (not to be confused with MHD power generation) was patented in 1961, it needs superconducting magnets to work most effectively. MHD thrusters use the Lorentz force, also called Fleming's left-hand rule: an electric current



A magnetic levitation railroad may use one of two basic approaches. Electrodynamic suspension [left] uses the repulsion of magnets in the train and railbed. It allows a larger tolerance (100 mm) and costs less, but yields a rougher ride. Japan's National Railroad Demonstration is testing this method. Electromagnetic suspension [right] uses attraction between magnets in the support structure and magnets in the train body that wraps around the support. It has a tighter tolerance (10 mm) and thus costs more, but provides a smoother ride. It is being tested by the German Transrapid Demonstration and will be used in Orlando's MTI demonstration.

perpendicular to a magnetic field produces a force perpendicular to that plane. In this case, the current and field go through sea water which is pushed down the tunnel [see illustration, p. 69].

Daniel Swallom, director of military power systems at Textron Defense Systems, Everett, Mass., said the only previous field trial was a 408-kg torpedo with conventional electromagnets in the early 1960s. A Japanese consortium, which includes Mitsubishi Heavy Industries Ltd., Tokyo, took up the technology in the 1970s and developed Yamato over the last eight years at a cost of $40 million. Yamato is about 30 meters long and 10 meters across the beam, and displaces 168 metric tons. Refrigeration and power systems occupy most of the ship, cramming the crew into a forward control room.

Despite Yamato's size, the two MHD thrusters (port and starboard) are remarkably small. Each comprises six tunnels, each 25 cm wide, 350 cm long, and encircled by niobium titanium superconductor coils cooled to 4 K. (High-temperature superconductors, working at 70 K, are needed to make MHD more practical by reducing refrigeration requirements.) The design represents a compromise between what could be achieved technically and what could be accommodated financially. Swallom said that the larger the MHD engines are, the more efficient they become because the volume increases faster than surface area (a single 61-cm tube would have only 40 percent of the surface area of six 25-cm tubes, but the same volume).

Swallom does not look for a similar demonstration in the United States because the commercial U.S. shipbuilding industry has all but disappeared. Most of the U.S. MHD work done is Textron's study and a 1/50-scale test model of a thruster, both sponsored by the Defense Advanced Research Projects Agency (Darpa), Arlington, Va. Newport News, Va.-based Shipbuilding & Drydock, one of the United States' two submarine builders, recently completed a year-long thruster test at the Argonne National Laboratory and is eyeing tests with an unmanned submersible.

Textron's work determined that a 35-MW power plant plus an MHD thruster shroud around the stern could drive an attack submarine at 56 km/h (30 knots) under water far more quietly than a conventional sub. Yamato's builders like to compare their vessel to Fulton's steamboat, which moved slightly slower on its maiden voyage in 1807, and foresee MHD tankers and freighters traversing the Pacific Ocean at 185 km/h (100 knots).

KEEPING IN TOUCH. MCI Government Systems in Washington, D.C., was contracted to install a new Leased Interfacility National airspace Communications System (Lincs) to reduce voice and data outages between the Federal Aviation Administration's (FAA's) air traffic control centers. These occur about once a month and last two to four hours.

Michael Gariazzo, FAA assistant manager for telecommunications management in Washington, D.C., said that MCI was proceeding rapidly and should have Seattle outfitted this month and Los Angeles soon thereafter. Lincs will comprise dedicated multiple optical-fiber links and transmitters plus rapid intelligent switching so the system automatically restores itself in 20–30 seconds.

Ironically, many network failures occurred because AT&T attached too many connections to too few digital optical-fiber lines; copper cables, because of their number, degrade more gradually. Lincs will involve 14 000 voice and data circuits connecting 5000 locations along multiple lines so that no single failure can black out the system. It is to be installed at the FAA's largest facilities by August and be complete by late 1994.

NEW SWITCHES, LINKS. Also to assist air traffic control, Harris Corp., Atlanta, Ga., is working on a complementary voice switching and control system (VSCS). The $1.7 billion contract followed a six-year development competition with AT&T. The system will use Harris's 20-20 optical-fiber digital telephone switch to route air-to-ground and ground-to-ground communications within en-route centers. The contract is for 25 systems, with an option for 24 more. The FAA is also buying low-density microwave links from Alcatel Network Systems Inc. of Richardson, Texas, for point-to-point applications including remote sites, and a new-generation data-multiplexing network (with speeds up to 24 kb/s) from Codex Corp., Mansfield, Mass.

In other areas of air transportation:

- Integration of Europe's air traffic control system proceeded haltingly as the member states grappled with sovereignty issues. No serious technical problems are expected to hamper the European ATC Harmonization and Integration Programme.
- The FAA awarded a $3.5 billion contract to IBM Corp. to upgrade the national air traffic control system.
- The FAA and the U.S. Air Force were working to make precision signals from the Navstar Global Positioning Satellites more widely available to airliners.
- A Federal judge found Pan Am failed to protect the ill-fated flight 103 (bombed over Scotland in 1988), and thus removed it from protection under the Warsaw Convention that limits damages to $75 000 per person. The first award was set two weeks later at $9.2 million.

CHUNNEL CHUGS ALONG. Crews continued outfitting the three tubes comprising the English Channel tunnel (Chunnel), even though the Eurotunnel consortium announced that it would not go into service until the third quarter of this year. Rising costs and technical problems were blamed. Shuttle trains between terminals are planned for this year, through trains for mid-1994, and overnight sleeper trains for 1995. A second chunnel was authorized to link Sweden and Denmark under the straits leading into the Baltic Sea. ◆

Aerospace and military

- **Peace batters defense industry**
- **Third World emerges as nuclear threat**
- **Bonn strafes European Fighter Aircraft**
- **Single international space program predicted**

Peace and the recession forced many defense companies to retrench and threatened several major defense and space projects. The aerospace and military industry will see military sales decline sharply and civil aircraft production become the prime driver for industry sales as companies make the difficult transition to peace, predicted Don Fuqua, president of the Aerospace Industries Association, Washington, D.C.

Consolidation is likely to be the way of the future. In late November, Martin Marietta Corp., Bethesda, Md., acquired the aerospace division of General Electric Co., Fairfield, Conn. for US $3 billion. General Dynamics Corp., St. Louis, Mo., sold its $1-billion-a-year missile division to Hughes Aircraft Co., Los Angeles, making Hughes one of the world's largest manufacturers of tactical missiles. In September, Hughes announced it would lay off 4000 workers, and consolidate remaining work at its Tucson, Ariz., facility. And last month, Lockheed Corp., Burbank, Calif., announced it is buying the Fort Worth, Tex.-based fighter jet division of General Dynamics for $1.5 billion.

ARMS CONTROL IMPROVES. With the United States and Russia reducing their large arsenals, attention turned to other nations that could become a greater threat as weapons technology spreads. Iraq already came close to building a nuclear bomb [''How Iraq reverse-engineered the bomb,'' *IEEE Spectrum*, April, pp. 20–24, 63–64]. Iran for a while seemed to have taken a direct route when rumors spread that it had acquired two tactical nuclear weapons from arsenals in Kazakhstan, Central Asia. Jon Wolfsthal, an analyst with the Arms Control Association, Washington, D.C., said that the weapons were on a test range and had not been properly inventoried. The incident highlighted concerns about Third World powers that lack the discipline of larger nations.

Overall, though, according to Wolfsthal, last year's efforts at arms control offered hope. Major nuclear suppliers—27 nations, including the European Community—agreed in April to strengthen control of items that have nuclear as well as conventional use and to require customers to accept comprehensive safeguards set up by the International Atomic Energy Agency (IAEA) in Vienna, Austria, as a condition of supply. The IAEA established a two-person office to analyze intelligence data from member states.

In February, Russia disclosed that two nuclear scientists had been offered—and declined—salaries equal to $24 000 a year to work for Libya. Such incidents led Russian President Boris Yeltsin and U.S. Secretary of State James Baker to plan a scientists' clearinghouse to monitor projects employing nuclear scientists in the Commonwealth of Independent States (CIS).

As the potential missile threat shifted, the Russians seemed to agree that the Antiballistic Missile (ABM) Treaty should be modified, said James Abrahamson, chairman of Oracle Inc., Menlo Park, Calif., and a former director of the U.S. Strategic Defense Initiative Organization (SDIO). Because missile control in this era is becoming impossible, Abrahamson said he can foresee an international situation where a small nation having just 15–20 missiles with chemical warheads can threaten major cities. Such a capability is not technically very challenging, he said.

This possibility was highlighted by reports that Iran and Syria had acquired ballistic missiles from North Korea and China. To cope with Persian Gulf War-style conflicts, the Pentagon rearranged its missile defense programs to provide more advanced short- and medium-range missiles. SDIO director Henry Cooper ordered the armed services to reorganize their missile defense activities as Project Executive Offices for the Global Protection Against Limited Strikes (GPALS). These offices will acquire support from existing Pentagon organizations.

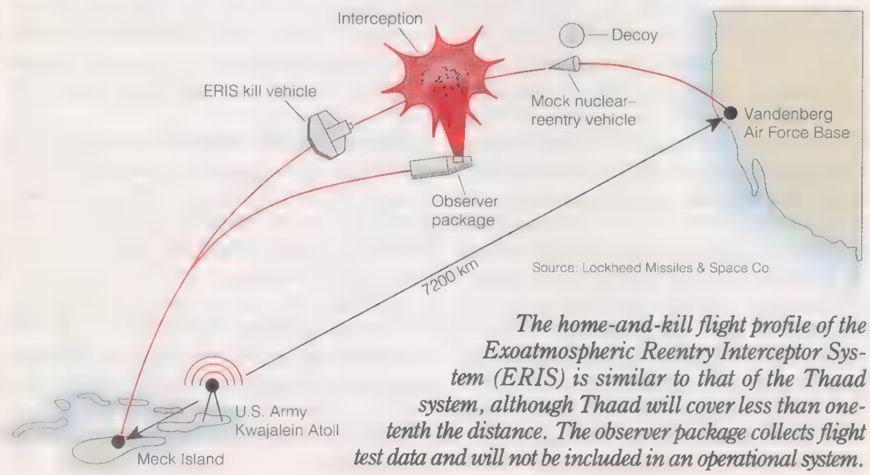
NEW ANTI-MISSILE PROGRAM. The Army was the first service to comply, forming the National Missile Defense and the Theater Missile Defense Program Offices in August. Their first weapon system is the Theater High Altitude Area Defense (Thaad), to be developed by a team led by Lockheed Missiles & Space Co., Sunnyvale, Calif., under a $689 million, four-year contract awarded in September.

As the upper layer of a two-tier defense, Thaad will ram incoming missiles head-on, at ranges greater than 160 km, thus reducing the chance that civilians will be hit by falling debris (as happened when Patriots intercepted Scuds close to the ground in Israel) and allowing chemical or biological warheads to disperse at high altitude. An upgraded PAC-3 Patriot will protect the lower layer.

In a Thaad engagement, a missile launch is detected by early-warning satellites (as Scuds were in the Gulf War) and the theater command is alerted. Satellites, airborne warning radar, and other systems track the target, then hand off to Thaad's battle management/command, control, communications, and intelligence (BM/C³I) system, which launches a Thaad missile.

Ground-based radar guides the Thaad to the target. Once it is above the thickest part of the atmosphere, on-board infrared seekers scan the sky and locate the target as a hot spot against the cold background of space. Seekers and avionics then command precision, rapid-fire thrusters to aim Thaad in a kamikaze sprint to the missile. Just before impact, a metal-studded ring inflates to enlarge Thaad and its chance of striking the missile.

Dave Dooling Contributing Editor



The home-and-kill flight profile of the Exoatmospheric Reentry Interceptor System (ERIS) is similar to that of the Thaad system, although Thaad will cover less than one-tenth the distance. The observer package collects flight test data and will not be included in an operational system.

For now, Lockheed's team is tasked with developing and delivering two BM/C^{3}I stations, 20 test missiles, launchers, and support gear by the mid-1990s. They will be available for use in a national emergency, the Army claims. Ground-based radars will be developed under a separate contract worth up to $600 million.

As for the other services, the U.S. Navy was planning to protect amphibious operations by adapting the shipboard Aegis air defense system, mainly with software upgrades, much as the U.S. Army did with Patriot. And the U.S. Air Force has proposed that it take over all ground-based air defense systems with a range greater than 3 km and leave the Army with just shoulder-launched missiles.

In an unexpected twist, Russian President Yeltsin suggested that Russia join GPALS to protect the world against accidental, rogue, or third-world launches. This would employ many of the 100 000 Soviet scientists, engineers, and technicians who might otherwise be lured into Third World weapons programs. By mid-summer SDIO teams were talking with their Moscow counterparts about joint missile projects.

Key elements of the Thaad system are based on two separate test programs, the Exoatmospheric Reentry Vehicle Interception System (ERIS) and the Light Exoatmospheric Projectile (LEAP). Last year, ERIS hit one target in a test on Feb. 4, then missed in its final test on March 13; the Army, though, claimed that most test objectives were met.

The Pentagon claimed some remarkable advances by LEAP, including miniature solid-and liquid-propellant systems to propel and guide the vehicle. However, LEAP failed to score an intercept in its first flight test at White Sands (N.M.) Missile Range.

HIGHLIGHTS

Success: Space station operations were foreshadowed by Spacelab missions with international crews and complex experiments.

Shortfall: Questions were raised about the accuracy of the Patriot air defense missile and missile defense in general.

Notable: Russia seeks U.S. cooperation in fields ranging from space station lifeboats to global nuclear protection.

Newsmaker: NASA astronauts rescued a stranded satellite.

EXPERT OPINION: Peace is transforming aerospace and military industries

MALCOLM R. CURRIE

The aerospace and defense industry is undergoing a profound and lasting transformation at a quickening pace as defense procurement budgets fall even faster than predicted, current contracts end, and international competition intensifies.

With major downsizing and restructuring under way or planned, the industry several years from now will look quite different from today. A new team of dominant players will emerge and, in a number of sectors, will reflect a trend toward intertwining and balancing commercial and government business. Efforts to diversify into related areas such as telecommunications, transportation, and environmental systems offer risk and reward, but in no case will they completely take up the employment slack.

Early in 1992 the Department of Defense (DOD) announced a new acquisition policy. It emphasizes strong R&D, advanced technology demonstrations (prototyping), and few new systems entering engineering development or manufacture. On the positive side, the DOD clearly intends to maintain a high level of advanced technology development even in the face of declining budgets.

Further, many opportunities will arise for significantly upgrading current system capabilities by injecting new technologies, so defense electronics should suffer less than others. On the other hand, industry does have concerns about retaining highly skilled capabilities for high-quality efficient production that has taken years to build and will not be easily recaptured.

Key questions for industry are: what technologies will be most important? What products and specific capabilities will be needed and procured? How are young college graduates to be attracted to what may be perceived as a fading industry? Companies will need to make some clear strategic choices that determine much of their future.

The answers lie partly in what potential conflict scenarios lie ahead in a world of proliferation and of many potential regional instabilities. What lessons can we learn from the Gulf War, a war that (in retrospect) was almost a benign environment compared to potential new conflicts? What will the heightened public expectations of virtually zero casualties dictate in terms of weapons systems? What opportunities will be created by the revolutionary pace of basic commercial technology, which in some areas is far ahead of military technologies? These and similar considerations will dominate our thinking and define the opportunities.

Setting the stage for the future, the DOD has announced seven major technological thrusts: global surveillance and communications; precision strike; air superiority and defense; sea control and undersea superiority; advanced land combat; synthetic environments; and technology for affordability.

'The U.S. Congress has finally endorsed the concept of the Defense Advanced Research Projects Agency pursuing dual-use technologies fundamental both to defense and commercial applications.'

Certainly, defense against long-range missiles will be an essential national priority as these technologies proliferate. Simulation will become increasingly important, not only in the design of systems and subsystems, but also for distributed simulations of combat and for testing new concepts. Software will continue to be a headache for the DOD and will consume enormous resources. The process of defining requirements and executing rigorous software design and maintaining the final configuration requires more attention.

The U.S. Defense Advanced Research Projects Agency (Darpa) will be given an increasingly important role in defining future defense technologies. Congress has finally endorsed the concept of Darpa pursuing dual-use technologies fundamental both to defense and commercial applications. A two-track road map for the future will address, on one hand, large, complex software-dominated systems and, on the other, basic technologies for the devices, sensors, and subsystems on which those systems depend.

Manufacturing technology programs will be continued, many of which have been highly successful recently. Improvements to and uses for stealth technology will continue to grow, as will emphasis on materials and electronic packaging. Real-time global surveillance and associated communications for command and control obviously are crucial for the future, as was emphasized by the Gulf War.

On the NASA side, new emphasis will be given to aeronautics R&D, one of the few major industries in which the United States dominates the market and has a favorable balance of trade. The Mission to Planet Earth is being redefined to encompass several smaller platforms rather than a few giant ones. Assimilating the torrent of data represents a new dimension in handling vast relational data-bases.

An explosion in new forms of worldwide telecommunications offers many opportunities for aerospace companies having systems and electronics capabilities. Similarly, advanced systems in the transportation sector offer potential.

Altogether, the period ahead is dynamic with great opportunities to succeed or fail. Success will go to those organizations with superior leadership, the ones that are lean, market-driven (both in defense and related commercial markets), and fast on their feet.

Malcolm R. Currie (F) retired last year as chairman and chief executive officer (CEO) of Hughes Aircraft Co., Los Angeles. He is a former U.S. undersecretary of defense for research and engineering.

In other SDI fields:

- The X-ray laser program—Edward Teller's centerpiece for a space-based defense—is to end this year without a weapon being demonstrated. Low power-conversion efficiency was a key problem.
- The Department of Defense declassified part of its adaptive optics technology, which reshapes laser beams to compensate for atmospheric distortion. Used in reverse, it can compensate for stars twinkling, a boon to astronomers.
- The United States canceled its SP-100 space reactor program in favor of buying Russia's once-secret Topaz 2; astronomers say its radiation emissions will interfere with observations by the Gamma Ray Observatory.

PATRIOT CRITICIZED. While Patriot's performance gave impetus to Thaad, Theodore Postol, a defense analyst at the Massachusetts Institute of Technology in Cambridge, claimed the Patriot was almost a total failure during the Gulf War. In the January 1992 issue of *International Security,* Postol wrote that most news videos of intercepts actually showed Scuds disintegrating under the forces of entry. Only one Scud was actually intercepted, at best, he said. The U.S. Army claimed an intercept ratio of 70 percent in the Saudi theater and 40 percent in the Israeli theater, while the Israeli Defence Force's claims were lower.

In September, the General Accounting Office reported that only 4 out of 47 could be substantiated with the Army's high-confidence data. The Army claims that no data can absolutely state how many Scuds were hit. So sensitive is the Army to this issue that it classified Postol's article, which he said used only unclassified sources.

EUROPEAN DOGFIGHT. Lack of a monolithic enemy cast doubt on the future of the European Fighter Aircraft (EFA) just as the first prototypes were being readied for test flights in 1993.

The twin-engine, delta-wing EFA is 14.5 meters long and 10.5 meters across the wingtips. Top speed will be more than Mach 1.8 with a combat radius greater than 500 km. Its nose canards improve maneuverability at the price of stability, which must be provided through fly-by-wire computers (pioneered by the U.S. X-29). Advanced technologies are used throughout: carbon-fiber composite and aluminum-lithium alloys in structures; a weapons and avionics suite that can engage eight targets at once; and integrated avionics to reduce pilot workload.

EFA development contracts were spread across Germany, Great Britain, Spain, and Italy; production also was to be shared. But rising costs and the high price of reunification prompted Germany to cancel its planned share of production. Many Germans perceived EFA as an anachronism—it was conceived to counter the Soviet military threat—and Defense Minister Volker Ruhe argued that everything except the aircraft itself had changed since it was started in 1984.

Last month, Ruhe agreed to a version of the EFA that Britain said would cost 30 percent less, but early production (which originally was to start last spring) has been deferred.

TURBULENT FLYING. In the United States, new tactical aircraft projects were off to rocky starts. A Lockheed-led consortium won the $12 billion Advanced Tactical Fighter contract in 1991 with its maneuverable, maintainable F-22 design. Last year, on April 25, the YF-22A prototype crashed at Edwards Air Force Base, Calif., after it porpoised during a low-level pass and the pilot belly-landed it on the desert. He walked away but the plane was a write-off.

On July 20, a prototype of the Marine Corps V-22 Osprey crashed into the Potomac River, killing seven crew and passengers, during its final approach to the Quantico, Va., Marine Corps Air Station. The V-22, a joint venture of Bell Helicopter Textron Inc., Fort Worth, Texas, and Boeing Vertol Co., Philadelphia, is to be used to ferry Marines from assault ships to shore. Although the Pentagon did not want the $1.5 billion program (and in March told Congress it could not stay on budget), Boeing and other companies lobbied hard and won strong Congressional approval.

Funding for a new Air Force attack version of the Navy's F/A-18 Hornet was halved and the Air Force was directed to use an upgraded F-16 Falcon. Some of the F-18 funds went to the Navy's AX, which will replace the canceled A-12 stealth attack jet. And the Air Force admitted that the B-2 stealth bomber would not be as invisible to radar as promised; the Administration sought funding for only 20 aircraft.

An even stealthier plane was rumored to be operating. In December, *Jane's Defence Weekly,* London, claimed that the U.S. Air Force was operating a methane-fueled, Mach 8 spy jet, code-named Aurora, that replaced the SR-71 Blackbird in 1989. *Aviation Week & Space Technology* had published reports that residents of Southern California had seen and heard phenomena that suggested Aurora uses a pulse jet or ramjet.

CIVIL AVIATION WARS. With air travel cut by the recession and revenues sliced even more by fare wars, the airlines idled about 10 percent of their fleets. The bankruptcies of Braniff, Pan Am, and TWA made used aircraft at auction more attractive than new ones.

Among companies who parted ways, United Air Lines Inc., Elk Grove Village, Ill., broke with Boeing Co., Seattle, Wash., as its sole supplier and agreed to lease 100 A320 jets from Airbus Industrie of France for $3 billion, $1 billion less than the price of the aircraft. Citing a lack of orders, McDonnell Douglas Corp., St. Louis, Mo., postponed its MD-12, a four-engine, double-decker jumbo jet that will seat up to 600 and compete with Boeing's 747. Noise requirements and the cost of operations and fuel will continue to press for replacement of the DC-9, 727, and other older aircraft with new models, Fuqua noted.

In October the National Research Council (NRC), Washington, D.C., cautioned that advances in onboard control, warning, and satellite navigation systems are needed if more passengers are to fly with fewer delays and accidents on the subsonic and short-haul aircraft that carry the most traffic. Before supersonic transportation can be practical, reductions in cost, air pollution, engine noise, and sonic booms must be achieved. The NRC noted that Airbus displaced McDonnell Douglas at second place in the world airliner market (Boeing Co. is No. 1).

At the National Aeronautics and Space Administration (NASA), Washington, D.C., new administrator Daniel S. Goldin announced plans to brainstorm with CEOs of airframe and engine manufacturers on a better balance between subsonic, supersonic, and hypersonic programs.

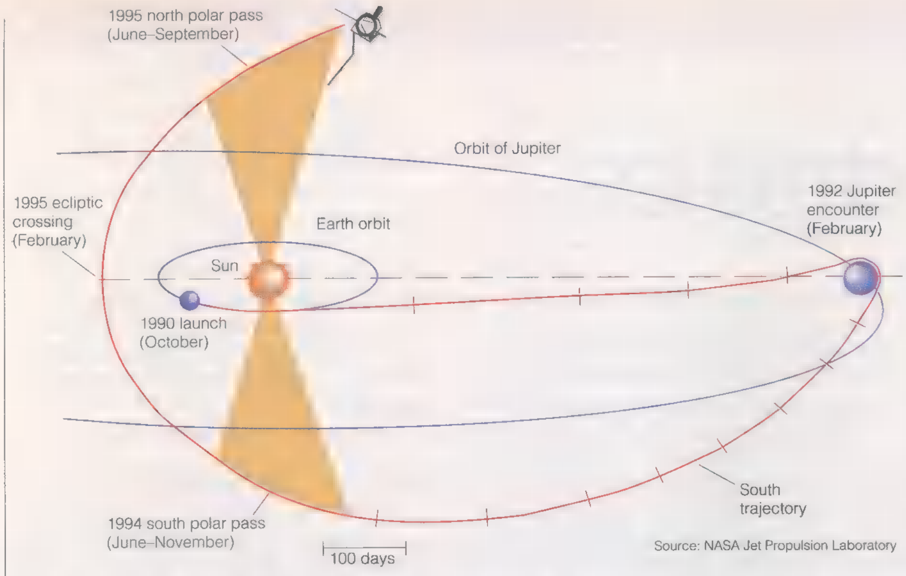
COOPERATION IN SPACE. Political and economic changes also portended large shifts in the world's space programs. Russia's opening of its gates may well reshape the whole method of "how we do business, what we plan, and where we go," said Andrew Stofan, chief executive officer of Analex Corp., Cleveland, Ohio, and a former head of NASA's space station program.

Stofan predicted that the long-term impact will be the formation of a single international space program. "More and more we are exploring the potential for enhanced international cooperation and burden sharing," agreed Ian Pryke, Washington, D.C., representative for the European Space Agency (ESA), based in Paris. "NASA will always be a significant partner, but we are also talking East as well as West in cooperation."

ESA has signed contracts worth more than $5 million with CIS to explore Russian space technology and obtain expert guidance on space station operations. In particular, the Hermes shuttlecraft, which this year was scaled back from manned vehicle to technology project, might become a joint Euro-Russian project, Pryke added. NASA is looking at using Russia's stalwart Soyuz spacecraft as a lifeboat for the astronauts aboard Space Station Freedom.

Stofan expects corporate opposition to evaporate. "They're going to scramble," he said. "If [companies] sit and holler protectionism, they're going to be left behind." Already Lockheed, Rockwell, United Technologies, and Loral have signed agreements with CIS companies.

A different kind of cooperation was eyed by Brian Dailey, new executive secretary of the National Space Council, Washington, D.C. Dailey said that last July the council began studying increasing the synergism between NASA and Department of Defense space programs and lowering managerial and technical walls. Some fear, however, that such cooperation might lead to the military control of civilian space activities. In Novem-



The trajectory for the Ulysses International Solar Polar Mission takes the spacecraft below the sun's south pole in June 1994. Measurements during the U-turn at Jupiter suggest that the solar wind drags on Jupiter's magnetic field and keeps it from rotating with the planet.

ber, the council's Space Policy Advisory Board said it would recommend that the Space Shuttle be phased out as soon as possible in favor of an Air Force–developed Spacelifter system operated by an Air Force–run national space launch authority.

UNDER NEW MANAGEMENT. Dan Goldin took over NASA in March after Vice President Dan Quayle fired administrator Richard Truly, the first astronaut to head the agency. (Whether the incoming Clinton administration will retain Goldin, a Democrat, is uncertain.) Goldin, formerly a vice president at TRW Space Defense Systems, Redondo Beach, Calif., has a reputation in the unmanned satellite community as an aggressive, talented manager. He ordered a review of the Space Station program with an eye toward launching it by the fastest means. Congress then amended NASA's funding to preclude any serious redesign.

James R. Thompson Jr., NASA deputy administrator under Truly and now a vice president with Orbital Sciences Corp., Fairfax, Va., said that NASA seems to be adjusting to reduced funding and fewer flights. "That's out of step with some very ambitious goals that were set forth by the [Bush] administration," Thompson said, especially just two years after the Augustine Commission recommended increased funding leading to a Mars exploration. "Today, we're no closer to Mars than we were when Bush made the announcement in 1989," Thompson noted.

ESA, too, is slowing down. "We're faced with the same sort of economic realities as NASA," Pryke said. The ESA Council, during a Nov. 9–10 meeting in Granada, Spain, decided to shift much of its emphasis from manned projects to unmanned earth observations.

NASA sailed high with several resoundingly successful Space Shuttle missions. Endeavour, Challenger's replacement and the last of the Shuttle orbiters, debuted with a high-flying rescue of an Intelsat VI satellite, left in a low orbit by a Titan III rocket in 1990. Initial attempts by two spacewalking astronauts to snag the large satellite were thwarted when a capture bar failed to work. In the first-ever three-man spacewalk staged, each astronaut gingerly grasped the satellite by the edge of its solar panel drum and attached the capture bar so the robot arm could place the satellite on a new rocket motor [cover photo].

Three Spacelab missions—International Microgravity Lab (IML-1), U.S. Microgravity Laboratory (USML-1), and the first Japanese mission (Spacelab-J)—investigated a range of low-gravity phenomena, and closely paralleled plans for Space Station Freedom, both in crew makeup and experiment suites. At two weeks, USML-1 also became the longest U.S. space flight since Skylab in 1974.

The shuttle also started a series of annual missions to monitor the atmosphere with instruments that can be precisely recalibrated on the ground. A mission to troll the Tethered Satellite System (TSS) through the earth's magnetic field on the end of a 20-km Kevlar-and-copper line was frustrated when the astronauts could unreel no more than 260 meters of tether; a small tension-relief nut added after ground tests jammed the line. That mission also deployed the 4491-kg European Retrievable Carrier, ESA's largest satellite.

These flights saw a record international mix for U.S. shuttle crews: five Europeans, one Canadian, and one Japanese. In November two Russian cosmonauts started training at NASA's Johnson Space Center, Houston, Texas, for a seat on the space shuttle this coming October; an American astronaut will make an extended tour aboard Mir in 1994.

Last year, Russia launched only two manned missions, both to the Mir space station. The first, in March, retrieved cosmonaut Sergei Krikalev; dubbed the Time Traveler by the Russian media, he had been kept aloft since May 1991 by the breakup of the USSR.

Miscellaneous groups are building their own launch facilities. The CIS formed a publicly held company to complete development of the large Energia-M launcher and planned to fire a modified SS-25 missile as a small satellite launcher. South Africa announced plans to enter the launch business by 1995. And the Consortium for Materials Development in Space, headquartered in Huntsville, Ala., is studying an oil platform in the Gulf of Mexico to launch suborbital rockets.

SATELLITES SHRINK. As part of the trend toward smaller satellites, NASA split the Advanced X-ray Astrophysics Facility (AXAF) into cheaper imaging and spectroscopy satellites. The Cassini orbiter/probe mission to Saturn and Titan was scaled down, and more authority was vested in technical managers to reduce costs. And the Earth Observing System was changed into a series of evolutionary satellites, with some major instruments deferred or canceled; $3 billion should be saved. NASA also started sifting through proposals for new "Discovery-class" planetary missions that are anticipated to cost $150 million and be launched in just three years.

On other frontiers:

- Two ESA probes reached milestones. Ulysses made a hairpin turn around Jupiter on Feb. 8 and headed for a high pass over the sun's south pole. Giotto, which flew past Halley's Comet in 1986, was reawakened for a successful July 10 encounter with Comet Grigg-Skjellerup.
- Both the European Ariane (carrying two communications satellites) and the U.S. Space Shuttle (Spacelab J) achieved their 50th launches.
- The Hubble Space Telescope made a comeback with the first high-resolution images of Jupiter's polar aurora, among other finds.
- Several science satellites were launched, including the Extreme Ultraviolet Explorer (an all-sky survey in the 7–76-nm spectrum), the Geotail spacecraft for the International Solar-Terrestrial Physics Program, and the Poseidon ocean topography experiment (Topex), the largest Franco-American project.
- NASA launched Mars Observer, its first mission to the Red Planet since the 1970s' Viking landers. It will survey the planet's surface and chemical composition.
- Pioneer Venus Orbiter, which arrived at Venus in 1978, burned up in the atmosphere in mid-October. Budget woes and ailing transmitters prompted NASA to plan on shutting down the Magellan radar mapper after a gravity contour survey planned for this year. ◆

Medical electronics

- New implantable defibrillators keep closer tabs on the heart
- Lasers sculpt and shrink corneas
- Biosensors help monitor blood gases
- FDA delays decried

Scientists made much progress in developing a variety of innovative devices that diagnose and treat health problems or aid basic biomedical research. But frustration with the Food and Drug Administration's unprecedented delays in approving medical devices in the United States darkened the industry's mood.

One particularly active area of medical electronics has been the new implantable defibrillators that have been described as "personal paramedics" for people at risk of developing life-threatening heart rhythms. Since the 1985 introduction of the devices, biomedical engineers continually refined the lifesaving implants, which deliver electric shocks to restore an abnormally beating heart to normal. The implants also often replace the risky drugs used for heart arrhythmias—medications that might provoke the fatal rhythms they are supposed to prevent.

Recent reports indicate that the more sophisticated generation of implantable defibrillators provides a substantial advance in treating such patients as cardiac arrest survivors.

Several companies, including Cardiac Pacemakers, Intermedics, Medtronic, Siemens Pacesetter, Telectronics Pacing Systems, and Ventritex, have been developing and testing third-generation devices, some of which are already available outside the United States. The only commercially available first- and second-generation implantable defibrillators, various models of the Ventak AICD, are produced by Cardiac Pacemakers Inc. (CPI), St. Paul, Minn.

Two companies have third-generation implantable devices poised to enter the U.S. market: Medtronic Inc., Minneapolis, Minn., with its PCD (pacer-cardioverter-defibrillator) system, which has been on the market in Europe since March 1991, and Ventritex Inc., Sunnyvale, Calif., with its Cadence system. In early 1992, an expert panel recommended the devices be approved for marketing. Both companies hope to have Food and Drug Administration (FDA) approval by early this year.

Joan Stephenson Contributing Editor,

Implantable defibrillators have two elements. One is a pulse generator, which contains a battery, capacitors, and the device's electronic circuitry. The other is a system of insulated, flexible wires that connect the pulse generator to the heart. The lead system detects the electrical signals of each heart beat and delivers electrical pulses to the heart when required. The surgeon attaches the leads' business ends to the heart; the other ends connect to the pulse generator, implanted under the skin of the abdomen.

The onset of an attack is detectable from the depolarizations moving through the heart muscle. The defibrillator's mission is to correct abnormal heart rhythms, such as ventricular tachycardia or ventricular fibrillation. In the first, the heart's slower pumping chambers, the ventricles, beat too rapidly; in the second, the ventricles quiver chaotically rather than contracting in an organized fashion.

FEWER SHOCKS. The new implantable defibrillators improve on earlier models in several ways. For example, they can respond to the rhythm abnormalities they detect with stepped, or tiered, therapy to correct the problem before the heart action accelerates to more dangerous levels. As a result, they are less likely to deliver inappropriate shocks—and when they do go into action, they can correct abnormal heart rhythms with mild impulses rather than painful jolts that some patients liken to "being kicked in the chest by a horse." If the heart fails to respond properly, the device steps up the shock intensity as needed.

Some patients who would benefit from implantable defibrillators also require a pacemaker to correct an abnormally slow heart rhythm called bradycardia—but the two devices operating independently can interfere with each other. The newer defibrillators solve this problem by incorporating a pacemaker.

HIGHLIGHTS

Success: Experimental surgery using excimer lasers corrects nearsightedness in an approach that could change ophthalmological practice.
Shortfall: Implantable defibrillators blessed by an expert panel are still awaiting approval by the U.S. Food and Drug Administration (FDA).
Notable: Researchers reported that an improved kind of implantable defibrillator reduces patients' risk of developing life-threatening heart rhythms.
Newsmaker: The FDA gave marketing approval to only 12 major innovative medical devices, unleashing a storm of criticism from manufacturers and industry groups.

Ventritex's Cadence defibrillator offers another advance: the ability to store recordings of the heart's activity immediately before and after the device has fired. Such recordings permit physicians to distinguish between, for example, an appropriate shock delivered to prevent a potentially fatal arrhythmia and a spurious one due to a faulty lead that needs to be replaced. The recordings are retrieved noninvasively, with an external device that uses short-range radiowaves to communicate with the implant.

Another feature, the use of biphasic shocks, appears to lower the energy required to defibrillate the heart in some patients. This development could translate to longer battery life and a smaller device.

Although the standard technique for implanting the devices involves opening up the chest cavity, surgeons are beginning to use a less risky technique in which two leads are threaded through blood vessels into the heart. (Heart tissue grows around the leads, holding them in place.) A third lead is implanted and sutured in position in subcutaneous tissue near the lower left side of the ribs [Fig. 1]. This less invasive approach makes the device an option for people too frail to withstand open-heart surgery. CPI and Medtronic have applied for FDA clearance of this type of lead system.

GETTING SMALLER. Future generations of implantable defibrillators are likely to be smaller. Today's models are about the size of a bar of soap, and shrinking them further will require new kinds of batteries and capacitors. Defibrillator manufacturers, who currently use aluminum electrolytic photoflash capacitors, are working on custom capacitors that will help reduce implant size.

Defibrillator researchers are also striving for better ways to discriminate between heart rhythms. Most implants deliver a shock when the heart rate goes up to a preset level. But in some individuals, a higher rate merely signals greater physical exertion—so the device might fire off a spurious shot during a tennis game, for example.

A way to directly measure the force and flow of circulating blood would indicate if a patient with an implant actually needed a shock. Developing sensors for this is a formidable challenge, however, because they must survive conditions inside the veins and

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arteries—a feat akin to sitting in a tub full of warm salt water for 10 years and withstanding hundreds of millions of mechanical fatigue cycles.

KEEPING AN EYE ON LASERS. Another promising area is the development of ophthalmic lasers that correct vision by reshaping the eye. During 1992, U.S. physicians were finishing up the final round of experimental surgeries using excimer lasers to correct myopia (nearsightedness)—an approach that proponents say will change the way ophthalmologists practice.

The technique that is sparking interest, photo-refractive keratectomy (PRK), uses a 15–30-second zap from an excimer laser to ablate, or sculpt away, a few layers of cells from the surface of the cornea, the eye's transparent outer layer. In a nearsighted person, the cornea focuses incoming light rays too far in front of the retina. PRK slightly flattens the cornea so the rays are focused right on the retina, correcting the problem.

For this technique, a computer supplied with refractive data determines how much tissue to remove. The laser beam is then aimed through an iris diaphragm, which controls its width.

Excimer sculpting is generally viewed as a marked improvement on an earlier surgical technique, radial keratotomy (RK). This method also corrects nearsightedness by changing the shape of the cornea. But because it employs a diamond-tipped scalpel to cut deep slits more than 90 percent through the cornea to flatten the eye, it weakens the tissue.

In contrast, excimer-sculpting pares away only 10–15 percent of the corneal thickness. And because excimers use short pulses of high-energy ultraviolet light, which break molecular bonds while generating little heat, the procedure leaves nearby tissue undamaged.

TWO LEADERS. Because PRK is in its infancy, long-term complications—if any—are not yet known. Two companies are leading the way in excimer-laser PRK in the United States. Summit Technology Inc., Waltham, Mass., and Visx Inc., Sunnyvale, Calif. Summit's Excimed UV2000, an ophthalmic

EXPERT OPINION: Imaging and robotics are changing the face of surgery

JAMES F. MARTIN

Each significant advance in endoscopic surgery—using a tubelike viewing instrument to operate through an incision or orifice—has been preceded by an innovation in imaging technology.

The breakthrough that sparked the recent explosion in endoscopic surgery was the invention of the computer chip video camera in the 1980s, which enabled assistants to share in viewing an operation's progress. The trend continues. Currently, three-chip cameras, integrated systems, and three-dimensional videosystems are being developed.

The three-chip camera has sensors for each primary color: red, green, and blue. Transmitting a video signal for each color produces truer and more detailed images. However, because the improvement the three-chip camera provides is too slight to justify its much higher cost, the single-chip camera still dominates the market.

Medical visualization systems now consist of separate components—endoscope, camera, light source, and adaptors—integrated by an equipment distributor and sold to the enduser. In the next year or two, the integration will be done by the manufacturers, producing a single system superior in function and performance to today's products.

A truly outstanding advance in medical visualization is the development of three-dimensional video. Two-dimensional images deprive endoscopic surgeons of the depth perception they have in open surgical procedures, which in turn raises the risk of complications and drags out operating time. To compensate, many endoscopic surgical devices have been specifically designed for 2-D visualization, such as instruments that hook and lift vessels before the surgeon cuts them or ties them cff.

With 3-D video, the endoscopic surgeon will once again have depth perception, increasing safety and reducing operating time. It also may simplify the design of endoscopic surgical instruments.

In the future, surgical imaging will not be limited to 2-D or 3-D video. Alternative imaging modalities may replace the senses lost or reduced in the performance of endoscopic operations, the most important of which is touch. Currently, endoscopic surgeons cannot distinguish between healthy and diseased tissue simply by touch, nor can they feel hollow-body organs and vessels to probe for blockages—for example, a stone blocking a duct leading from the gallbladder. To help "see" into hollow-body organs and vessels, endoscopic surgeons are beginning to use intraoperative ultrasound imaging.

During cancer surgery, the surgeon often tells healthy from cancerous tissue in part by touch. For such surgery to be performed endoscopically, this sense of touch must be replaced.

'Within a decade, surgeons may operate on patients without even being in the same location.'

Recently, to image cancerous tissue externally, researchers have explored using monoclonal antibodies that are tagged radioactively and directed against tumor-associated antigens. Work is already in progress to develop handheld gamma detection probes to identify cancerous lesions. Investigators are also exploring other ways to tag monoclonal antibodies. Fluorescent labels, say, might provide the same level of specificity without the complications of radioactive half-life.

In addition to imaging innovations, there is robotics. Robotic, or computer-assisted surgery, is an extension of stereotaxic surgery, in which instruments are precisely positioned by means of a mechanical reference system. Stereotaxic systems are typically used in biopsies and some forms of brain surgery. In 1991, veterinary researchers extended this technology to orthopedic surgery, using a robotic arm to carve the femoral cavity for insertion of a prosthetic hip joint. In milling the cavity, the arm relies on magnetic resonance images and preoperative planning by the physician.

Currently, endoscopic procedures require a camera operator whose sole responsibility is to keep the camera focused where the surgeon is working. A robotic arm connected to the operating table, and either voice-activated or controlled by foot pedals, can replace the camera operator and may improve the stability of the video image. In the long run, robotic arms may replace the surgical assistant in retracting tissues and organs.

Within a decade, endoscopic surgeons may operate on patients remotely, by interacting with a stereoscopic image augmented with tactile and auditory feedback. The goal of "telepresence" surgical systems is to define a space within the body, which would be viewed through an internal 3-D camera manipulated by a robotic arm.

Various computer-controlled surgical instruments would be introduced through additional entry ports. These computer-controlled instruments would be articulated, providing a greater degree of freedom than current endoscopic instruments. When the surgeon's controls are grasped, the remote manipulators appear in the image of the patient's body and move precisely as if they were in the surgeon's hands.

Is telepresence the natural extension of today's endoscopic surgery? The answer depends heavily on whether the computer-based tools can provide the control and sensory inputs necessary to address the subtle aspects of both human anatomy and surgical skill. Nevertheless, research on overcoming the limitations of today's endoscopic techniques, particularly in visualization and precise instrument control, should pay off with enhancements to current equipment.

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excimer-laser system (which includes a built-in microscope and a computer), was used in U.S. clinical trials and is already widely used in Europe and Asia.

Visx has two excimer-laser systems in trials for corneal sculpting. The Twenty/Twenty excimer and the Excimer 2015, which include operating microscopes, video displays, computer software, and diagnostic equipment, are used for PRK as well as for treating superficial scars and certain eye problems that cause a clouding of the front of the cornea. Visx is also selling its laser systems worldwide through marketing partner Alcon Laboratories Inc., Fort Worth, Tex.

Although corneal sculpting with excimers is still regarded as experimental in the United States, it has been widely performed since the late 1980s on about 30 000 patients in western Europe and Asia. According to Irving J. Arons, a technical consultant with Arthur D. Little Inc., Cambridge, Mass., non-U.S. companies developing excimer laser systems include Aesculap-Meditec GmbH, Tuttlingen, Germany, and Nidek Co., Gamagori, Japan. So far, only Aesculap-Meditec has a substantial number of units in the field being used for PRK.

Summit's first experiments with the technique were performed in the late 1980s by John Marshall in England and Theo Seiler, then in West Germany, and results helped win PRK's acceptance abroad. Summit president David Muller said the company's system has treated about 12 000–13 000 non-U.S. patients.

A two-year follow-up of the final group of patients in the U.S. excimer clinical trials is under way. If it proceeds as expected, the companies involved are likely to submit their premarket-approval applications to the FDA in 1994. Depending on how quickly the agency acts, the use of excimer sculpting to treat nearsightedness in the United States could be approved by 1995. The systems are expected to cost about $400 000 each.

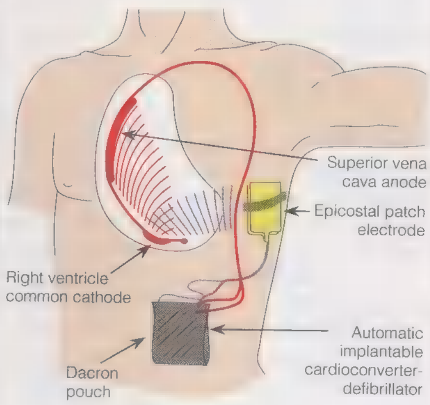
Researchers are trying a couple of strategies in treating two other vision problems: hyperopia (farsightedness) and astigmatism (irregular corneal curvature, which causes distorted or blurred vision). Correcting those conditions calls for more selective removal of corneal tissue—a tougher proposition than flattening the front to cure nearsightedness. Reporting some success, Visx has treated astigmatism using a beam-shaping system, while Summit is testing an erodible mask—a thin plastic template that matches the correction called for by the computer algorithms. The mask is placed in the path of the laser, above the cornea, and as it is vaporized, its shape is replicated inversely on the patient's cornea.

An alternative approach to eye surgery under investigation uses solid-state lasers to remove or shrink tissue below the corneal surface. It is said to avoid some of the disadvantages of excimer sculpting, such as extreme pain during healing and thickening of the corneal surface.

Sunrise Technologies, Fremont, Calif., is testing a holmium laser system, which changes the shape of the cornea by using infrared energy to heat and selectively shrink collagen, a tissue protein. Two other companies, Intelligent Surgical Lasers Inc., San Diego, Calif., and Phoenix Laser Systems Inc., San Francisco, Calif., are testing solid-state neodymium lasers to change corneal shape by selectively removing, rather than shrinking, tissue within the cornea.

SENSIBLE TECHNOLOGY. Biosensors, detection devices that marry biological materials with electronics, have been around for decades. But until recently, the technology rarely made the leap from lab bench to marketplace, as would-be developers of biosensor-based products wrestled with problems ranging from instability to cost.

Commercial products based on biosensors are emerging, however, thanks to advances in a number of areas and the expectation that products using biosensors be more efficient and cost less than current approaches. The competition is expected to be fierce, involving dozens of companies, from start-ups to established biomedical firms.



[1] One version of the new kind of automatic implantable cardioconverter defibrillator, enclosed in a Dacron pouch, delivers a shock to the heart through three electrodes. The single cathode is located in the heart's right ventricle, one anode is in the superior vena cava (a major vein into the heart), and the other is above a rib in the left chest wall. Source: Nicholas G. Tullo et al., "Technological Improvements in Future Implantable Defibrillators," Cardio, *May 1990, pp. 107–111*

The biological component of this kind of biosensor includes a highly specific enzyme, antibody, or other molecule that reacts with the substance to be measured. Thyroid hormone or viral proteins are examples. The electronic component measures a change in voltage, current, light, temperature, or other factor due to the chemical reaction.

Perhaps the most significant clinical advance to use biosensor technology is blood gas monitoring, which provides continuous readings of the gases in the blood of patients in surgery or intensive care. The developer of one such device, Puritan-Bennett Corp., Overland Park, Kan., began shipping its PB3300 intra-arterial blood-gas–monitoring system to buyers last September.

The biosensor in the PB3300 system packages a thermocouple (to provide blood temperature readings) as well as three sensors (optical fibers, each tipped with a different fluorescent dye) into a unit slender enough to be inserted into a radial artery. High-energy photons transmitted through the fibers are absorbed by the dyes; the re-emitted light intensities are proportional to concentrations of nearby oxygen, carbon dioxide, and hydrogen ions. The system converts this data and displays it as readings of O_2, CO_2, and pH.

Analysts estimate a potential market for continuous blood-gas monitors of about $500 million to $1 billion a year, so Puritan-Bennett is likely to have a lot of competition. Other firms expected to market such devices are Abbott Laboratories, North Chicago, Ill., and Biomedical Sensors, part of the Pfizer Hospital Products Group, Middlesex, England.

Some companies are using biosensors in devices meant for biomedical and pharmaceutical research or for large-scale cell-culturing systems, such as those used in the biotechnology industry. Molecular Devices Corp., Menlo Park, Calif., for example, recently introduced its Cytosensor Microphysiometer, which monitors the metabolism of living cells. The system detects real-time response of cells by monitoring their rate of acidification for sudden changes due to, say, drugs or toxins.

The heart of the device, a small chamber containing living cells sandwiched between two membranes, sits atop silicon chips sealed with an insulating layer. The system periodically halts the flow of a fresh nutrient solution through the chamber, to allow acidic waste products to build up. When a chemical reaction occurs in the cells, the chips adsorb released protons or electrons, and their electrical potential changes.

As the cells respond to test molecules pumped over them, their metabolic rate goes up and the chips monitor that rise. "The silicon-chip sensors function as a very sensitive pH meter, converting pH to an electronic signal in a low noise-sensitive manner," said Wally Parce, Molecular Devices' vice president of research.

Adeza Biomedical, Biocircuits, BioStar, i-Stat Corp., Pharmacia, and Spectrum Diagnostics are among the many firms attempting to develop diagnostic tests using biosensor technologies. The intent is to devise tests for hard-to-detect substances or to create faster tests that are easier to administer at the bedside or in the doctor's office.

One biosensor-based diagnostic tool finding its way into critical-care units since its introduction last spring is a handheld blood analyzer developed by i-Stat Corp., Princeton, N.J. The half-kilogram i-Stat System, which is designed for bedside use, consists

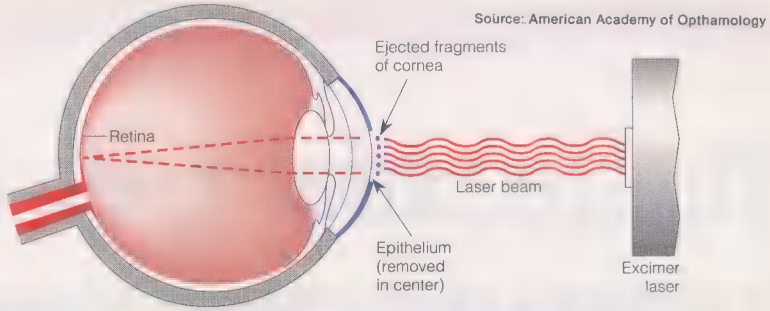
of a microprocessor roughly the size of a cellular telephone and a disposable cartridge that contains biosensors on the surface of silicon chips.

The biosensors react electrically to the six blood components being tested, including glucose, sodium, and potassium. In 90 seconds, the microprocessor converts the electric signals and displays the data on the screen. The device's main advantages are speed and perhaps even cost savings—a doctor or nurse can operate the device on the spot, bypassing the hospital lab or other remote facility. Furthermore, the analyzer's immediate feedback means that treatment can be more quickly adjusted, if needed.

Although i-Stat's portability and speed may appeal to medical facilities seeking a point-of-care blood analyzer, the competition for this huge market is considerable. Mallinckrodt Inc., Hazelwood, Mo., for example, markets an analyzer that is somewhat larger but will measure blood gases as well as electrolytes. Other possible competitors include firms that currently make the large analyzers used in the central clinical labs, such as Abbott Laboratories, Baxter International, Eastman Kodak, and Miles.

Other upcoming biosensor-based diagnostic point-of-care systems include a device for testing thyroid disorders that Biocircuits Corp., Burlingame, Calif., plans to introduce this year. A test for detecting chlamydia, the microbe behind a common sexually transmitted disease, is also in the works, and tests for other analytes will follow to expand the list.

Source: American Academy of Opthamology



Carmen A. Puliafito, New England Eye Center, Tufts University School of Medicine, Boston

[2] In experimental surgery to correct nearsightedness, an excimer laser produces shock waves that flatten the center of the cornea by fragmenting its epithelium, or outer layer. The slightly flattened shape focuses light properly onto the retina. The photo below the diagram shows a tiny mushroom cloud of tissue being vaporized off the cornea.

At the core of Biocircuits' diagnostic system is an ultrathin membrane consisting of a combination of proteins, lipids, and polymers, housed in a disposable cartridge. Proteins such as antibodies, customized to bind with the substance to be detected, are attached to a film consisting of lipids bound together in a polymer. The lipids form ultrathin membranes compatible with blood and other body fluids; the polymers provide stability.

The polymers also make the film highly fluorescent and act as an optical transducer to convert the binding of a hormone or other analyte to the membrane into measurable test results. The binding event alters the membrane's optical properties such that its fluorescence dims in proportion to the number of molecules of the test substance in the sample. A light-emitting diode (in the system's desktop measuring instrument) shines on the membrane to create a fluorescent signal, and a photodiode quantitatively records the change in fluorescence.

REGULATORY WRANGLING. Despite progress in developing new medical products, unprecedented delays by the FDA in approving them frustrated many in the $35-billion-a-year industry.

The move toward stricter regulation hit the headlines last year, with the controversy over silicone breast implants. That issue grew out of the FDA's attempts to reexamine more than 100 products that were already on the market in 1976, the year Congress charged the agency with regulating medical devices as well as food and drugs.

The regulatory heat was cranked up another notch with the 1990 Safe Medical Devices Act, which, among other things, requires medical-device manufacturers to track where some implantable products go. Industry representatives complain this requirement did not reckon with the complexity of the undertaking.

But anger has been generated by the FDA's slowness in reviewing applications for new products. "The product approval process has slowed down to a trickle," said Alan H. Magazine, president of the Health Industry Manufacturers Association, based in Washington, D.C. The agency granted marketing approval for 12 higher-risk medical devices in the fiscal year that ended September 1992, compared with 47 in the same period in 1991 and 56 approvals in 1990.

"It's true if you look at numbers, there aren't as many PMAs [pre-marketing approvals for a class of higher-risk devices] this year as last year, but our main focus is on safety and effectiveness, and not numbers," said Sharon Snider, an FDA spokeswoman. In the agency's view, the device evaluation process has been operating virtually unchanged, despite a great deal of Congressional oversight and other matters that have taken up a lot of FDA time, she said.

However, approval times have climbed as well, according to data released by the FDA's Office of Device Evaluation. For products receiving pre-market approval in fiscal 1991, the process took 633 days from submission, up from 415 days in fiscal 1990 and 348 days in fiscal 1989. To a lesser extent, industry members say the review process is delaying the advent of improved versions of existing devices.

Alan Magazine and others feel the regulatory climate is prompting U.S. companies to move more R&D and manufacturing facilities abroad to countries with less stringent oversight. Moreover, industry members said that the current regulatory situation is dampening the ability of U.S. companies to compete internationally.

Industry representatives are beginning to see a "glimmer of hope" in working with the FDA toward a more agreeable regulatory climate, said Magazine. The Department of Health and Human Services set up an internal task force to examine the FDA's impact on the medical devices industry, particularly with respect to product approvals, and the agency has indicated it is willing to discuss relevant issues with industry representatives.

"We have a long way to go," said Magazine. "But there are some indications that things are changing." ◆

The specialties

- **Can multimedia live up to the hype?**
- **Magnetic media store more to the millimeter**
- **Curricula must cram more in**

Multimedia, magnetic materials and technologies, and engineering education are all at the center of change. The first is challenged by the vast storage capacity needed for handling full-motion television images; the second may meet that challenge by increased storage density, signal-to-noise ratio, and access times; and the third is weighing interdisciplinary approaches.

GOOD COMMUNICATION. "The most difficult problem facing communicators today is figuring out how to use and control burgeoning communication vehicles and techniques," declared David L. McKown, member of the Administrative Committee (Adcom) of the IEEE Professional Communication Society.

First, consider multimedia, "a term loosely used to describe almost everything that does not result in a piece of paper," McKown observed, but more properly described as a suite of communications technologies, one that unites huge reserves of storage with access to text, still and animated graphics, photographs, video, and sound.

While entertainment is the main objective of much of today's multimedia, the technology is cutting deep swaths in marketing and training disciplines. All the same, if multimedia is to catch on with audiences long accustomed to commercial television, full-motion video is a must, McKown observed. Here, the biggest problem is the extraordinary data storage capacity required, he said.

Just one frame of broadcast-quality video occupies half a megabyte of storage, and 30 frames must be handled each second. Storing even a 30-second video presentation requires close to 500 megabytes. Although current technology can compress about an hour of video into the same 500 megabytes, that hour leaves only some 150 megabytes on a typical compact-disc ROM (CD ROM) for data and software for manipulating the video. Thus "there is a critical need for increasingly efficient data compression techniques in the form of dedicated chip sets," McKown contended.

Data storage and retrieval is the bottleneck. Technologically, they have the longest way to go before true multimedia can become a reality. That upshot may require compact discs with even greater data density, "or perhaps an entirely new kind of storage device," McKown said. It may also include innovative ways of compressing and decompressing data in real time, he added, "perhaps by a third-party carrier such as a telephone company or cable TV network."

DENSE STORAGE. A few recent developments in magnetism could be revolutionary for multimedia and other storage devices, according to Roger F. Hoyt, reporting for the IEEE Magnetics Society as a member of the Technical Activities Board's New Technology Directions Committee.

Current and emerging technologies are now all in quest of better signal-to-noise ratio performance, which allows both denser storage and faster access times, said Hoyt. That quest is being pursued in magnetic materials, read/write heads, and new physical effects useful for storage.

In the case of hard (or rigid) disks, Hoyt expects the surface thin-film media to take on system capacities of greater than 10 gigabytes. At present, the thin films dominate in the range from under 200 megabytes up to several gigabytes.

In high-density recording, moreover, two key developments in rigid disks were introduced last year. One is the heads introduced by IBM Corp. incorporating a magnetoresistive read element, which yield a higher signal-to-noise ratio than conventional technologies. Another is contact recording, disclosed by such companies as Censtor Inc. and Visqus Corp., of Mountain View and San Diego, Calif., respectively. In contact recording, the head flies less than 10 nm above the disk surface and so can read denser data.

Still to come are read heads based on the spin valve effect, of use for disks made of closely coupled magnetic layers. When one of these ferromagnetic layers is subjected to an external magnetic field, it seems that electrons having one kind of spin pass through that layer more efficiently than electrons of the opposite spin. In effect, the layer acts like a valve.

Magneto-optical storage devices arrived in volume last year. The technology will go on inspiring new applications for removable media, images, and libraries with capacities greater than 1 terabyte, Hoyt said.

In strictly optical storage, meanwhile, areal densities are looking up. In the foreseeable future, densities could just about double thanks to new laser sources that operate at wavelengths shorter than 430 nm. Over the next decade, further improvements may be realized through ongoing scientific work in such exotic techniques as near-field optics, holographic storage, or persistent spectral hole-burning.

Finally, magnetic-tape recorders may borrow from videocassette recording and use its well-established helical scanning head technology in data recorders or high-definition television applications, Hoyt said.

EDUCATIONAL UPDATE. "Influential voices are calling for major changes in undergraduate engineering education," noted Jerry R. Yeargan, president of the IEEE Education Society. Technologies rather than disciplines are what draw engineers to specific industries. Academia therefore should match its programs to broader educational goals rather than to traditional courses and disciplines, in the view of scholars such as Joseph Bordogna, head of the engineering directorate of the U.S. National Science Foundation in Washington, D.C.

Others, such as Edward W. Ernst, Allied Signal Professor of Engineering at the University of South Carolina, have identified several aspects of undergraduate engineering education likely to change. One possibility is a shift of focus from the content of the courses more toward the development of young people as emerging professionals. Another is to enlarge the almost exclusive attention paid by the undergraduate program to technology and economics to a more inclusive curriculum of societal, political, and environmental factors as well.

Yet others, such as James G. Harris in the department of electrical engineering at California Polytechnic University in San Luis Obispo, want concerns for social security, rather than national security, to be central. Other needs listed are a greater awareness among engineering students of other cultures in a global economy, concurrent engineering, increased emphasis on design and manufacturing, and more emphasis on engineering for quality.

The main challenge, Yeargan pointed out, is how to introduce such interdisciplinary changes into the undergraduate engineering curriculum while still keeping to the standard four years of study. "These changes will evolve," he concluded, "and they will be achieved with improvements in student advising and retention, expanded use of workstations, education over communication links, [and] laboratory simulations." ◆

Trudy E. Bell Senior Editor

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New technology directions

- *IEEE committee names challenges*
- *Portfolio of emerging technologies*
- *Discovery of unsung disciplines*

Electrotechnology faces seven grand challenges, and if it surmounts all seven, many people (1) will be reachable at any time, anywhere, through worldwide personal communication networks and wirefree and fiberless communications, and (2) will have instant access to all information, through databases, high-speed links, and flat-panel displays and interfaces. A person may be (3) present at any time, anywhere, through virtual presence and reality. In the flesh, though, people will (4) enjoy abundant, clean, safe, and affordable energy, (5) travel faster and more safely over intelligent highways, (6) work in a paperless office, and (7) never carry cash, using instead an electronic purse or wallet.

That, more or less, is the conclusion of the New Technology Directions Committee (NTDC), a standing committee of the IEEE Technical Activities Board (TAB). NTDC is also part of an effort to keep the international standards community abreast of the most significant of the latest technical papers.

The technologies crucial to meeting the seven challenges are in many cases highlighted in an NTDC report, a "living document" that has grown in draft form almost every month. Called a *Portfolio of Emerging Technologies*, it is to be published in the committee's first annual bound volume this year, said NTDC chairman Martin Schneider.

The hope, said Schneider, is that the report will find several audiences: young engineers planning their careers, the IEEE technical societies and publications wanting to know what is ahead in their specialties, and entrepreneurs and investors.

HOTTEST FIELDS. The emerging technologies described in the *Portfolio* range from power electronics through diamond deposition to standards. A few highlights follow.

In power electronics, for instance, single thyristors with built-in control logic can now switch distribution system voltages of 8500 V and currents of 3500 A. Controllers incorporating such devices, it is anticipated, will manage energy flow at the speed of light, by varying impedance, phase angle, and voltage, rather than at the speeds of mechanical devices used today. That means service to big customers could be tailored to their moment-by-moment requirements.

An outstanding magnetic material recently introduced is neodymium iron boron with very high saturation flux density. Permanent magnets made of it will enable the design of more compact and efficient machinery.

In high-power microwaves, much is happening. In vacuum tubes, 2.6 MW of power have been generated with 73 percent efficiency at 1 GHz using a magnicon, and gyratrons can now produce up to 500 kW at frequencies up to 110 GHz. Solid-state silicon carbide devices can operate with a junction temperature of up to 500 °C, delivering 20 W in the 10-GHz band. One highly interesting application of high-power microwaves is in radioactive waste management. The half-life of this hazardous waste is reduced by an order of magnitude when a particle beam generated by high-power microwaves is passed through the dangerous material.

The plasma deposition of diamond, a Soviet discovery, is now being vigorously explored worldwide. Diamond is an excellent semiconductor for computer applications because of its thermal conductivity and other properties. Several plasma chemical vapor deposition configurations are promising, and all are surprisingly simple. The next steps include the need to increase the deposition rate and the substrate area that can be processed, the adhesion of the film to the substrate, the growth of single-crystal films, and the ability to grow diamond films on a wide variety of substrate materials.

Ideally, standards for the volt and ohm should be realized in terms of fundamental physical constants and counts of single electrons. Cryogenics has proven to be the technology needed here. For example, superconducting quantum interference devices (Squids) are very sensitive detectors of individual charges. Investigators at the National Institute of Standards and Technology (NIST), Gaithersburg, Md., have used a Squid to verify that voltages between two Josephson junction arrays were the same to within 1 part in 10^{17}. Defining and realizing the SI units (such as mass and length) in terms of fundamental constants of nature is also an emerging activity.

EMERGING STANDARDS. There is a void between technical papers and standards. At present, many international standards in electrotechnology are developed through the consensus procedures of the International Electrotechnical Commission (IEC), Geneva, Switzerland. But the IEC's General Policy Committee, in response to a 1990 study of its procedures, noted that technical documents of R&D efforts could serve as source documents for eventual consensus standards. It therefore recommended that the commission set up new mechanisms to introduce the documents to the global standards community.

For help, the IEC is looking toward organizations with strong technical activities, such as the IEEE, to provide inputs. The point of such a collaboration would be to give emerging technologies early and broad recognition, and to allow the best of them better access to the standards-setting process.

As a result, the NTDC is working with the New Opportunities in Standards Committee (NosCom) of the IEEE Standards Board on a series of documents called *IEC/IEEE Emerging Technical Practices and Procedures*. These will resemble the application notes published by industry, for besides serving as precursors for developing standards, they will also help EEs in the design, construction, and testing of components and systems.

Six of the documents, now in preparation, are expected later this year: "Design and Realization of Broadband Transmission Line Matching Networks," "Lasers as Flexible Tools in Manufacturing," "Noise Characterization of Solid-State Devices," "Fusion Reactor Control," "Modeling of Field-Effect Transistors," and "Erbium-Doped Fiber Amplifiers."

MORE COVERAGE. Part of NTDC's charter is to identify areas of technology not addressed by IEEE entities and to facilitate the formation of intersociety committees in such areas. Indeed, over the last year "we found areas not adequately covered" by any of the existing technical societies, NDTC chairman Schneider said. Four of them are flat-panel displays; materials in electrotechnology; the general area of health, safety, and the environment; and electric energy. Electric energy, in fact, ranked first in a 1991 NTDC survey of problems needing technical solutions. In response, TAB has appointed *ad hoc* committees in those areas.

NTDC has also begun creating videotapes on emerging technologies; last year saw the first—a video tutorial on microwave optoelectronics by Alwyn Seeds, co-produced by NTDC and the IEEE Educational Activities Department. Also in the cards is a distinguished lecturer program. ◆

Trudy E. Bell Senior Editor

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To probe further

THE MAIN EVENT. Eric Betzig and Jay K. Trautman give a succinct overview of near-field techniques and magneto-optical storage in their article, "Near-field Optics: Microscopy, Spectroscopy, and Surface Modification—Beyond the Diffraction Limit." It appeared in the July 10, 1992, issue of *AAAS Science*, pp. 189–95.

PCs AND WORKSTATIONS. Richard L. Sites, one of the architects of Digital Equipment Corp.'s Alpha chip, has edited the 600-page *Alpha Architecture Reference Manual* (Digital Press, Burlington, Mass., 1992), which looks in detail at the processor's instruction-set architecture and its support for VMS and OSF/1. Gerry Kane and Joe Heinrich describe the MIPS R4000 and other members of the R series in the second edition of *MIPS RISC Architecture* (Prentice Hall, Englewood Cliffs, N.J., 1991).

SOFTWARE. The architecture and design of Microsoft Corp.'s upcoming operating system are outlined in *Inside Windows NT* by Helen Custer (Microsoft Press, Redmond, Wash., 1992; 1-800-MSPRESS). The new notation for software is fully explained in the book, *Visualizing Software*, by William S. Bennett (Marcel Dekker, New York, 1992).

LARGE COMPUTERS. The entire September 1992 issue of *IEEE Spectrum* was devoted to supercomputing, emphasizing the emergence of massively parallel architectures and the race to produce a machine capable of one trillion operations per second.

TELECOMMUNICATIONS. For an account of the issues that the 1992 World Administrative Radio Conference was to address, see the special report "WARC's last act?" by Edward E. Reinhart et al. in the February 1992 issue of *Spectrum*, pp. 20–33. For a summary of the conference's results, see "New frequencies are allocated by WARC-92," by Trudy E. Bell, THE INSTITUTE, May/June 1992, p. 1 and p. 4.

The May 1992 issue of *IEEE Communications* was devoted to the topic of multimedia communications.

DATA COMMUNICATIONS. John McQuillan is the author of a wide-ranging ATM tutorial, "Cell Relay Switching: High-Speed Networks Take a Step Closer to the 21st Century," in *Data Communications*, September 1991, pp. 58–69.

Johna Till Johnson offers an excellent report on the National Research and Education Network (NREN) and associated activities in "NREN: Turning the Clock Ahead on Tomorrow's Networks," in *Data Communications*, September 1992, pp. 43–62.

SOLID STATE. A catalog listing of the 3-V ICs available from many manufacturers can be obtained through Intel Corp.'s FAXBACK system. To use the system, call 800-628-2282 with a facsimile machine equipped with touch-tone capability. Select document No. 2152 when instructed.

Copies of the *Digest of Papers* from the 1992 IEEE International Solid-State Circuits Conference (ISSCC) and information on registration at next year's conference can be obtained by contacting Diane Suiters, Courtesy Associates, 655 15th St., N.W, Washington, D.C. 20005; 202-639-4255.

TEST AND MEASUREMENT. A comprehensive look at how VXIbus is meshed with software in actual testing systems is to be found in *Test & Measurement World* for 1991. The February, April, June, and October issues contain a sequence of articles called "Constructing a VXIbus-based Test System."

The August 1992 *VXI Newsletter* from Bode Enterprises lists and describes all available (over 500) VXI types of equipment made by many vendors. The firm may be contacted at 8380 Hercules Dr., Suite P3, La Mesa, Calif. 91942; 619-697-8790.

INDUSTRIAL ELECTRONICS. Many applications can be found in the three-volume *Proceedings of the 1992 International Conference on Industrial Electronics, Control, Instrumentation and Automation*, Nov. 9–13, 1992, IEEE Publication No. 92CH3137-7. Contact the IEEE Service Center (address below).

POWER AND ENERGY. *The Electricity Journal* is a monthly publication with news and in-depth reports on critical issues in the utility industry. The journal's offices are at 1932 First Ave., Suite 809, Seattle, Wash. 98101; 206-448-4078. *IEEE Power Engineering Review*, published by the Power Engineering Society, contains articles of a technical nature and has Society news as well.

CONSUMER ELECTRONICS. For more information on ghost canceling, see "Good-bye to TV ghosts," by Ronald K. Jurgen, *Spectrum*, July 1992, pp. 50–52.

The latest consumer electronic products are exhibited by manufacturers twice a year at the International Winter and Summer Consumer Electronics Shows. Contact the Consumer Electronics Group, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, D.C. 20006-1813; 202-457-8700.

TRANSPORTATION. The May 1991 *Spectrum* surveyed IVHS technologies in "Smart cars and highways go global," pp. 26–36.

Daniel W. Swallom and colleagues provide an excellent tutorial on the subject in "Magnetohydrodynamic Submarine Propulsion Systems," published in *Naval Engineers Journal*, May 1991, pp. 141–57.

AEROSPACE AND MILITARY. The technology of intercepting incoming missiles and determining whether a hit was scored is outlined by Theodore A. Postol in "Lessons of the Gulf War Experience with Patriot," published in the January 1992 issue of *International Security*, pp. 119–171. The challenges facing subsonic civil aviation are explored in *Aeronautical Technologies for the 21st Century.* Copies are $38 from the National Academy Press, 2101 Constitution Ave., Box 285, Washington, D.C. 20055; 202-334-3313.

MEDICAL ELECTRONICS. The 15th Annual International Conference of the IEEE Engineering in Medicine and Biology Society will be held Oct. 28–31, 1993, at the Sheraton Harbor Island Hotel, San Diego, Calif. Contact Susan Blanchard at 919-493-3225.

THE SPECIALTIES. *Multimedia Applications Development Using DVI Technology* by Mark J. Bunzel and Sandra K. Morris (McGraw-Hill, New York, 1992) is a good introduction to the topic.

For more information on trends in magnetic storage, see the three-volume 1992 *Disk/Trend Report*. It is published by Disk/Trend Inc., 1925 Landings Dr., Mountain View, Calif. 94043; 415-961-6209.

For more information on trends in engineering education, see the *Proceedings of the Frontiers in Education 22nd Annual Conference* (92 CH3210-2), held Nov. 11–15, 1992. Edited by Laurence Grayson, it is available from the IEEE Service Center.

NEW TECHNOLOGY DIRECTIONS. To receive a copy of the current draft of the *Portfolio of Emerging Technologies*, contact Jayne Cerone by sending an e-mail message to info.new.technology@ieee.org.

For more on IEEE publications, contact the IEEE Service Center, 445 Hoes Lane, Piscataway, N.J. 08855-1331; 908-981-1393.

ACKNOWLEDGMENTS

This issue would not have been possible without the help of many experts in the IEEE technical societies who generously submitted material, and the many technical reviewers we called upon to critique the material planned for the issue before it was released for publication.

The pictures of the experts that appear with each major article in this issue were drawn by Barry Ross, Northampton, Mass.

Program Notes

(Continued from p. 19)

the basic options available with all C/C++ compilers. That is, level 0 is standard C compilation—no C++ code allowed—while level 3 is standard C++ compilation—all C++ constructs allowed.

"Incremental strength" is the province of levels 1 and 2. Level 1 is "weak" C++ compatibility. That is, most C++ rules are not enforced and, while almost all C++ features are available, they are accessed only through modified keywords (_Operator instead of operator, _Class instead of class, and so forth). So programs can be changed using either C or C++-like constructs without changing the rest of the code.

Level 2 is "strong" C++ compatibility; the only significant C++ rule not enforced is the requirement that every function have a prototype. C++ features are available through standard C++ keywords, programs must be changed using C++, and any of the rest of the code written in C must be C++-compliant.

In "Incremental strength" High C/C++, C programmers have a tool to begin writing code that is easy to convert to full C++ compatible source code at a later date. *Contact: MetaWare Inc., 2162 Delaware Ave., Santa Cruz, Calif. 95060-5706; 408-429-6382; or* **circle 111**.

Fortran's revival

All the emphasis on object-oriented languages like C++ and SmallTalk tends to obscure the fact that older program languages continue to change as computing environments change. Fortran, in particularly, is going through a growth spurt.

This growth in sales of Fortran-based applications has fueled demand for a better Fortran. A joint American National Standards Institute/International Standards Organization committee has been working for five years to satisfy that demand. Now, the work is finished and there is a new Fortran standard, Fortran 90—also known as ANSI X3.198-1992 or ISO/IEC 1539:1991(E).

New Fortran 90 features can be grouped under two headings: extensions of the Fortran language that make it more like Pascal and C, and enhancements of its number-crunching capability. C and Pascal programmers will find programming in Fortran 90 much more straight forward: it has the most useful features of C and Pascal, such as structures, pointers, dynamic memory allocation, and modern control structures (like DO WHILE and CASE). Also, Fortran 90 accepts freeform input like Pascal and C compilers. Numerical programmers will also find programming in Fortran 90 easier: it contains array expressions for determining the rank, extent and shape of an array, as well as functions for manipulating matrices that were left out of Fortran 77. Examples are functions that calculate the dot product of an array and which transpose arrays.

Lahey Computer Systems Inc., one of the leaders in the Fortran 90 movement, is marketing a collection of front-end tools called The Lahey Partnership Project that will speed converting existing compilers to Fortran 90. Compiler vendors can purchase from Lahey C code containing a lexer, run-time package, an intrinsic library, a debugger, and an environment for Fortran 90 as well as printed manuals. This code can be linked with the vendor's object code for optimization, code generation, and linking.

Most Fortran software vendors will be able to provide more detailed information on Fortran 90. Information on The Lahey Partnership Project is also available. *Contact: Guy Ceragioli, Lahey Computer Systems, Inc., 865 Tahoe Blvd., Box 6091, Incline Village, Nev. 89450; 702-831-2500; or* **circle 112**.

CONTRIBUTOR: John R. Hines is silicon sensors engineer at Honeywell Inc.'s MicroSwitch Division, Richardson, Texas
COORDINATOR: Richard Comerford

Legal aspects

(Continued from p. 20)

consistent with other cases in this area. However, on the issue of similarity, the decision broke new ground, departing from a fairly prominent decision in the computer software field, *Whelan Associates v. Jaslow Dental Laboratory*.

The *Whelan* case held that the structure, sequence, and organization of a program, in addition to the underlying source and object codes, are protected by copyright. Decided in 1986 by the U.S. Court of Appeals for the Third Circuit in Philadelphia, a sister court to the Second Circuit, *Whelan* has been followed by some courts and criticized by others. (Note that the Second and Third Circuit courts cover different geographical areas and the decisions of one court are not binding on the other. If a circuit court so chooses, it may follow the ruling of another. However, unreconcilable differences in opinion must be resolved by the U.S. Supreme Court.)

The difficulty the *Altai* court had with the *Whelan* decision was its premise that a program is a monolithic creation, consisting of only one idea. The Second Circuit disagreed with this notion, concluding that software packages are in reality a collection of individual but perhaps interacting components, each of which has to be examined separately for protectable authorship. Moreover, the court concluded that this approach more accurately reflects the practical realities of software design.

A TRIPARTITE TEST. With the foregoing in mind, the court fashioned a three-part test for determining whether the nonliteral elements of two different programs are substantially similar. Beginning with the premise that computer programs have at least several components, the first step is to separate the program into its "constituent structural parts," isolating the broad, abstract concept embodied in each part. Such concepts do not represent original authorship and therefore are not protectable under copyright.

For example, one subpart of the program might be responsible for sending data to a printer. Although that section might contain certain unique features, when all is said and done, it is simply a means of printing. Another component of the software might be concerned with a calculation using an algorithm, and so on.

Because the court set no limitation on the step of disassembling a program, one could arguably parse software until nothing remains but abstract concepts. Therefore, it is likely that this aspect will be revisited by another court.

The second step of the court's test is "filtration," a sifting out of all nonprotectable material in each of the components, leaving only that which could be truly protected by copyright. One category of nonprotectable material embraces components dictated by external factors, such as hardware specifics and limitations (like memory or word length), compatibility with other programs, and industry standards and practices—all of which would not be protectable and should be eliminated from consideration.

Another type of nonprotectable material is components included for efficiency's sake. Efficiency often dictates not only how a program is written, but also how it is structured. Other nonprotectable elements include mere ideas (such as the concept of printing) and items that are in the public domain.

DOWN TO THE CORE. Finally, in the third step, after the nonprotectable elements have been filtered out, what may be left is a "core of protectable expression," or what the court has called the "golden nugget." Now, and only now, should a side-by-side comparison of the two programs be made, taking into consideration the relative importance of what may have been copied to the overall work.

In comparing Oscar 3.5 with Adapter, the trial court determined that Oscar 3.5 contained "virtually no lines of code that were identical to ADAPTER." Looking beyond the literal code, the court found that perhaps a few, relatively unimportant parameter lists and macros were similar; to the extent there were other resemblances, they were not protected by copyright. On that basis, the court concluded that Oscar 3.5 was not substantially similar to Adapter and thus there was no infringement.

One interesting statement in the appellate court's decision concerns the issue of copyright in display screens. Technically speaking, the software code and the display screens created by that software are separate entities. The court recognized this, writing that "[i]f a computer audiovisual display is copyrighted separately as an audiovisual work, apart from the literary work that generates it (i.e., the program), the display may be protectable regardless of the underlying program's copyright status."

The court's statement would seem to imply that full protection of a software package that creates screen displays is achieved by filing two registrations: one for the code and another for the displays. However, as a practical matter, if you are contemplating registering a copyright for a software package, be advised that the Copyright Office will not accept two applications. Only one application covering both aspects may be filed—on the theory that any screen displays are the inherent result of the code and therefore a second registration would be redundant.

Joel Miller is an attorney in private practice in West Orange, N.J.

COORDINATOR: Trudy E. Bell

EEs' tools & toys

Celestial navigation with the HP 48SX

Old salts and weekend sailors alike can benefit from the Celestial Navigation Pac from Sparcom Corp. The software, which is contained in a plug-in expansion card for Hewlett-Packard Co.'s HP 48SX expandable scientific calculator, includes routines for blue-water sailing (celestial navigation) and piloting (sailing within sight of land). It also comes with an almanac accurate to the year 2030 with data on 268 stars, the sun, the moon, and all major planets and Messier objects.

The package easily handles great-circle, rhumb-line, and composite routes. At any time during a voyage, the navigator can enter the vessel's current position and destination, from which the Pac calculates the distance to go and the heading to steer.

In piloting, the Pac computes distances by both the vertical-angle and two-bearings methods. It also includes routines for performing time-speed-distance calculations, and for converting between magnetic and true directions.

The software package, complete with a 170-page manual, is available now for US $99.95. *Contact: Sparcom Corp., 897 N.W. Grant Ave., Corvallis, Ore. 97330; 503-757-8416; fax, 503-753-7821; or* **circle 101.**

INSTRUMENTATION

An ESD generator to go

Soon to be a legal requirement for the sale of electronic apparatus within the European Community, IEC standard 801-2 sets limits for susceptibility to electrostatic discharge (ESD) and describes procedures for measuring it. To help manufacturers make sure that their products meet that requirement, Schaffner EMC Inc. has developed the Model NSG 435 handheld ESD generator—an easy-to-use instrument that generates high-voltage pulses as specified in the standard.

Users of the microprocessor-controlled device simply punch in the desired voltage, number of discharges, polarity, and discharge type (air or contact), and then squeeze the trigger. The battery-operated instrument then delivers the requested out-

Schaffner EMC Inc.

A squeeze of the trigger on the NSG 435 ESD generator delivers a programmed train of pulses up to 16.5 kV for testing a device's susceptibility to electrostatic discharge.

EEs' tools & toys

put and displays the actual measured discharge voltage, allowing the user to verify that the desired output was delivered—that it did not bleed off prematurely. The NSG 435 can deliver up to 16.5 kV in its air discharge mode (which simulates a discharge from a human finger) and 9 kV in its contact mode (which simulates a discharge from a metallic object). A memory feature records setups for speedy test repetition.

The generator is programmable via an optical-fiber link for remote triggering and control. It sells for US $6900, and is available from stock. *Contact: Schaffner EMC Inc., 9-B Fadem Rd., Springfield, N.J. 07081; 201-379-7778; fax, 201-379-1151; or* **circle 102.**

SOFTWARE

Measuring software complexity

Since software bugs like to hide in complex code modules, measuring software complexity can be a valuable tool in searching them out. But how does one measure software complexity? One way—applicable to programs written in Ada, C, C^{++}, and Fortran—is to use Metric, a static code analyzer from Software Research Inc., which applies several complexity measures to source code and identifies the most complex parts.

The program automatically computes measures of both program size and control flow. To take just one example, Metric counts the number of unique operators and operands in a program module, and uses those numbers to predict the module's length. The ratio of the predicted length to the actual length is a meaningful measure of the module's complexity.

Other calculated measures include cyclomatic complexity (related to the number of conditional statements in the module and the number of consecutive nonconditional statements in a block), lines of code, blank lines of code, and mean maximum span of references for variables.

Based on such measures, Metric produces three reports: a complexity report, which lists the measures for each module; a summary report, which applies to the overall program, not the individual modules; and an exception report, which lists all the program modules that exceed user-defined metric thresholds.

Pricing is not yet firm, but it is likely to be in the range of US $2500–$3000 for a three-seat license for Metric alone. The program will also be offered in combination with other Software Research products. *Contact: Software Research Inc., 625 Third St., San Francisco, Calif. 94107-1997; 415-957-1441; toll-free, 800-942-7638; fax, 415-957-0730; or* **circle 103.**

POWER AND ENERGY

Shock prevention

The U.S. National Electrical Safety Code (NESC), which has been adopted as the law in 48 states, describes procedures for safeguarding people against electrical hazards. Replacing the 1989 version, the 1993 NESC is available from the IEEE along with a companion handbook that contains the additional facts, figures, and detailed explanations needed to implement the NESC effectively.

Separately, the 1993 NESC and NESC Handbook list for US $39.50 and $65.00, respectively. They are also offered as a set for $80. For IEEE members, the prices are $27.65 for the NESC, $45.50 for the NESC Handbook, and $70 for the set. *Contact: IEEE Standards, Box 1331, Piscataway, N.J. 08855-1331; 908-562-3824; or* **circle 104.**

COORDINATOR: Michael J. Riezenman
CONSULTANT: Paul A.T. Wolfgang, Boeing Defense & Space Group

Graphics

(Continued from p.18)
Banchoff's work involves classifying and comparing singularities on projections of surfaces in 4-D space, seeing how a singularity changes as the object that contains it is rotated, for example. With each new discovery comes a little more knowledge about 4-D space, he explained, and more processing power means the ability to investigate, interactively, more complex singularities in more complex figures.

Earlier this year, for example, Banchoff and his undergraduate students produced "a new Klein bottle rendition that we like very much." A Klein bottle is created by taking a flexible cylinder and joining the end edges, but with a twist. Rather than forming the familiar doughnut-shaped ring, one end of the cylinder is turned up and passed through the cylinder in such a way that the ends approach from the other side. In four dimensions, however, there is no such invasion. In Banchoff's new image, color coding indicates where the parts of the Klein bottle are in relation to each other in 4-D space: red is the highest, and green is the lowest [photo, p. 18]. (Two years ago, Banchoff's book, *Beyond the Third Dimension*, was published by W.H. Freeman & Co. in New York.)

The sticking point of using workstations to project 4-D objects into three dimensions is, of course, that pesky 2-D display screen. Rotating images on the screen is the time-honored way of giving the viewer enough clues to grasp the 3-D structure, but computer science professor Andrew J. Hanson of Indiana University believes that adding visual detail may give even more clues. After all, it is shading and other details, he argues, that lets a viewer instantly recognize a 3-D world in a 2-D picture.

Viewed from the side, a spiral, if it is just a thread-like line, might just as easily be a series of loops in a flat plane. Here the plot literally thickens. Fattening up that line into a shiny tube immediately reveals the spiral structure, Hanson noted. Graphics software he developed with student Pheng Heng extends this same idea to the 4-D realm.

In the 3-D case, computer graphics creates the shiny tube by moving a shiny ring—the cross section of the tube-to-be—over the line. The plane of the ring is always perpendicular to the line, and the line moves right through the center of the ring.

The 4-D case is merely more complex. Take a surface in 4-D space, for example. At every point, there are two vectors that determine the "direction" of the surface at that point. In four dimensions, there are two other directions "left over"—a plane. This plane, which is perpendicular to the two vectors in the surface, is then swept all over the surface in order to thicken it.

Can this really be envisioned in four dimensions? "It's nontrivial," Hanson concedes.

Once the image is thickened in this way, conventional graphics software renders it on the screen. Of course, there are a few major rendering differences: in 4-D, the viewing region is volumetric and figures are divided into tetrahedrons, as opposed to planar and divided into triangles; and the depth buffer is the w-buffer, rather than z.

All of which begs the question, how do you view 4-D projections in three dimensions? Researchers have used red-green anaglyph stereograms, the fancy name for the process exploited to bring depth, so to speak, to those 1950s' B-thrillers. Lately, Hanson has been using cross-eyed stereo pairs, in which slightly different left and right images are printed side by side and some centimeters apart. Crossing the eyes in just the right way lets the viewer see a third, 3-D image floating in between the two images.

Hanson is looking forward to trying out workstation-based 3-D viewing systems that use special eyeglasses with liquid-crystal shutters to route the different left- and right-eye images. Such systems are produced by StereoGraphics Corp. in San Rafael, Calif., and Tektronix Inc. in Beaverton, Ore.

COORDINATOR: Glenn Zorpette

Employment opportunities

Organizations seeking engineers and scientists describe their various openings in the following advertising section
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Calendar

(Continued from p. 18H)

Ion and Photon Beams (ED); June 1–4; Sheraton Harbor Island, San Diego, Calif.; Fritz J. Hohn, IBM Research Division, Thomas J. Watson Research Center, Box 218, Yorktown Heights, N.Y. 10598; 914-945-1608; fax, 914-945-4121.

Conference on Insulating Films on Semiconductors—Infos '93 (ED); June 2–5; Delft University of Technology, the Netherlands; C.H. Klein, Conference Office Infos '93, DIMES, Delft University of Technology, Box 5053, 2600 GB Delft, The Netherlands; (31+15) 783 868; fax, (31+15) 622 163.

International Solid-State Sensors and Actuators Conference (ED); June 7–10; Pacific Convention Plaza, Yokohama, Japan; K. Takahashi, Department of Physical Electronics, Tokyo Institute of Technology, Ohokayama Meguro-Ku, Tokyo, Japan; fax, (81+33) 748 3135.

12th International Conference on Consumer Electronics (CE); June 8–10; Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, Conference Coordinator, 67 Raspberry Patch Dr., Rochester, N.Y. 14612-2868; 716-392-3862.

International Workshop on Charge-Coupled Devices and Advanced Image Sensors (ED); June 9–11; University of Waterloo, Ontario; Savaas Chamberlain, University of Waterloo, Electronic Computer Engineering Department, Waterloo, Ont., Canada N2L 3G1; 519-888-4598; fax, 519-746-6321.

Microwave and Millimeter Wave Monolithic Circuits Symposium (ED); June 14–15; Marriott Hotel, Atlanta, Ga.; Charles Huang, LRW Associates, 1218 Balfour Dr., Arnold, Md. 21012; 301-647-1591; fax, 301-647-5136.

National Telesystems Conference—NTC 1993 (AES et al.); June 16–17; Georgia World Congress Center, Atlanta; Eric N. Barnhart, Communications Laboratory, Georgia Tech Research Institute, Atlanta, Ga. 30332-0800; 404-894-8248; fax, 404-894-3906.

Device Research Conference (ED); June 21–23; University of California at Santa Barbara; Thomas N. Jackson, Thomas J. Watson Research Center, Box 218, MS 30-156, Yorktown Heights, N.Y. 10598; 914-945-1947; fax, 914-945-3688.

Pulsed Power Conference (ED); June 21–24; Hyatt Regency Hotel, Albuquerque, N.M.; Janet Scowle, Sandia National Laboratory, Department 1240, Albuquerque, N.M. 87185; 505-845-7000; fax, 505-845-7003.

14th International Conference on Applications and Theory of Petri Nets (C); June 21–25; Bismarck Hotel, Chicago; T. Murata or S. Shatz, EECS Department, University of Illinois at Chicago, Box 4348, Chicago, Ill. 60680; 312-996-5488.

JULY

International Vacuum Microelectronics Conference (ED); July 12–15; Hotel Viking, Newport, R.I.; Charles A. Spindt, SRI, 333 Ravenswood Ave., Menlo Park, Calif. 94025; 415-859-2993; fax, 415-859-3090.

International Semiconductor Manufacturing Science Symposium (ED); July 19–21; San Francisco Marriott, San Francisco; Eileen Vierra, Semi, 805 East Middlefield Rd., Mountainview, Calif. 94043; 415-940-6988; fax, 415-967-5375.

International Microprocess Confer-

Calendar

ence (ED); July 19–22; International Conference Center Hiroshima, Hiroshima, Japan; Susumu Namba, Business Center, 5-16-9 Honkomagome, Bunkyo-ku, Tokyo 113, Japan; (81+3) 5814-5800.

30th Annual IEEE Nuclear and Space Radiation Effects Conference (NPS); July 19–23; Snowbird Ski and Summer Resort, Snowbird, Utah; James R. Schwank, Sandia National Laboratories, Department 1332, Box 5800, Albuquerque, N.M. 87185; 505-844-8376.

AUGUST

Cornell Conference on Advanced Concepts in High Speed Semiconductor Devices and Circuits (ED); Aug. 2–4; Cornell University, Ithaca, N.Y.; Pallab Bhattacharya, Department of Electrical Engineers, University of Michigan, 1301 Beal Ave., Ann Arbor, Minn. 48109-2122; 313-763-6678; fax, 313-747-1781.

Intersociety Energy Conversion Engineering Conference (ED); Aug. 8–13; Hyatt Regency Hotel, Atlanta, Ga.; Diane Ruddy, American Chemical Society, 1155 16th St., N.W., Washington, D.C. 20036; 202-872-4600.

International Conference on the Applications of Diamond Films and Related Materials (ED); Aug. 25–27; Sonic City Hall, Omiya Saitama, Japan; ADC '93 Secretariat, International Communications Inc., Kasho Building 2-14-9 Nihombashi, Chno-ku, Tokyo 103, Japan.

International Conference on Solid-State Devices and Materials (ED); Aug. 29–Sept. 1; Nippon Convention Center, Chiba City, Japan; SSDM Secretariat, c/o Business Center for Academic Societies Japan, Honkomagome 5-16-9, Bunkyo-ku, Tokyo 113, Japan; (81+3) 5814 5800.

SEPTEMBER

Fourth European Conference on Electron and Optical Beam Testing of Electronic Devices (R); Sept. 1–3; Swiss Federal Institute of Technology (ETH), Zurich; Mauro Ciappo, Reliability Laboratory, ETH-Zentrum, CH-8092 Zurich, Switzerland; (41+1) 256 2436; fax, (41+1) 251 2172.

Athens Power Tech—Planning, Operation and Control in Today's Electric Power Systems (PE, Greece Section); Sept. 5–7; Athens Concert Hall, Greece; B.C. Papadias, National Technical University of Athens, Electric Energy Systems Laboratory, Patission St. 42, Athens 106 82, Greece; (30+1) 360 0551 or 361 1983.

Fifth International Conference on Simulation of Semiconductor Devices and Processes (ED); Sept. 7–9; Technical University of Vienna, Austria; Siegfried Selberherr, Institute of Microelectronics, Gusshausstrasse 27-29/E360, A-1040 Vienna, Austria; (43+1) 58801 3855.

Second Network Management and Control Workshop (C); Sept. 21–23; Westchester Marriott Hotel, Tarrytown, N.Y.; Judy Keller, IEEE Communications Society, 345 East 47th St., New York, N.Y. 10017; 212-705-7365; fax, 212-705-7865.

OCTOBER

International Conference on Computer Design: VLSI in Computers and Processors (ED); Oct. 3–6; Royal Sonesta Hotel, Cambridge, Mass., IEEE Computer Society, 1730 Massachusetts Ave., N.W., Washington, D.C. 20036-1903; 202-371-1013; fax, 202-728-0884.

Recent books

The Telecommunications Revolution: Past, Present and Future. Eds. *Sapolsky, Harvey M., et al.*, Routledge, Chapman and Hall, New York, 1992, 217 pp., $49.95.

Contrarian Management: Commonsense Antidotes to Business Fads and Fallacies. *Smith, Martin R.*, Amacom, New York, 1992, 240 pp., $21.95.

Energy-Efficient Electric Motors: Selection and Application, 2nd edition. *Andreas, John C.*, Marcel Dekker, New York, 1992, 288 pp., $69.75.

Manufacturing Strategy: Process and Content. *Voss, Christopher A.*, Routledge, Chapman & Hall, New York, 1992, 402 pp., $69.95.

Learning & Running MS-DOS 5. *Microsoft*, Microsoft Press, Redmond, Wash., 1991, 592 pp., $39.95.

Designing and Building Electronic Filters. *Horn, Delton T.*, TAB/McGraw-Hill, Blue Ridge Summit, Pa., 1992, 240 pp., $14.95.

Decline and Fall of the American Programmer. *Yourdon, Edward*, Yourdon Press/Prentice Hall, Englewood Cliffs, N.J., 1992, 360 pp., $24.95.

Dan Gookin's PC Hotline. *Gookin, Dan*, Microsoft Press, Redmond, Wash., 1992, 256 pp., $14.95.

Lenk's RF Handbook: Operation and Troubleshooting. *Lenk, John D.*, McGraw-Hill, New York, 1992, 304 pp., $39.95.

Intelligent Robotic Systems for Space Exploration. Ed. *Desrochers, Alan A.*, Kluwer Academic, Dordrecht, the Netherlands, 1992, 342 pp., $89.95.

Microsoft Publisher. *Simone, Luisa*, Microsoft Press, Redmond, Wash., 1992, 392 pp., $24.95.

An Introduction to Morphological Image Processing. *Dougherty, Edward R.*, SPIE Optical Engineering Press, Bellingham, Wash., 1992, 175 pp., $42.

Software Implementation Techniques. *Merusi, Donald E.*, Digital Press, Burlington, Mass., 1992, 743 pp., $39.95.

Steinmetz: Engineer and Socialist. *Kline, Ronald R.*, Johns Hopkins University Press, Baltimore, Md., 1992, 401 pp., $39.95.

The Apple Macintosh Book, 4th edition. *Lu, Cary*, Microsoft Press, Redmond, Wash., 1992, 528 pp., $24.95.

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Equipment, procedures, and techniques applicable to the organization, installation, and operation of functional systems meeting high-performance requirements of earth and space systems. (4)
Jack R. Harris, 20400 Highland Hall Dr., Gaithersburg, MD 20879 301-251-4810

Aerospace and Electronic Systems Magazine
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H. Warren Cooper, 7211 Windsor Lane, Hyattsville, MD 20782 301-927-7681

Annals of the History of Computing
Chronicles vital contributions and their impact on society. Departments: Happenings; Biographies; Anecdotes; Self-Study Q&A; Reviews; and Comments, Queries, and Debate. (4)
J.A.N. Lee, V.A. Tech., 133 McBride Hall, Blacksburg, VA 24061 703-231-6705

Antennas and Propagation, IEEE Trans
.Experimental and theoretical advances in electromagnetic theory and in the radiation, propagation, scattering and diffraction of electromagnetic waves, and the devices, media and fields of application pertinent thereto such as antennas, plasmas, and radio astronomy systems. (12)
Ronald J. Marhefka, Electroscience Labs, Ohio State University, 1320 Kinnear Rd., Columbus, OH 43212-1191

Antennas and Propagation Magazine
Antenna theory, design and practice; propagation, theory and effects; and a broad range of general interest topics including basic electromagnetics, computational and numerical techniques, personal computers for EEs, scattering and diffraction, radar and radar cross sections. (6)
W. Ross Stone, Expersoft Corp., 1446 Vista Claridad, La Jolla, CA 92037 619-597-8727

Applied Superconductivity, IEEE Trans.
Contains articles on the applications of superconductivity and relevant technology. Electronic applications include analog and digital circuits employing thin films and active devices such as Josephson junctions. Power applications include magnet design as well as motors, generators, and power transmission. (4)
Theodore Van Duzer, Dept. of EECS, University of California, Berkeley, CA 94720
415-642-3306

Automatic Control, IEEE Trans.
The theory, design, and application of control systems: real-time control, optimal control, adaptive and stochastic control, estimation and identification, linear systems, system modeling, and applications of physical, economic and social systems. (12)
John Baillieul, Department of Aerospace/Mechanical Engineering, Boston University, 110 Cummington St., Boston, MA 02215
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Biomedical Engineering, IEEE Trans.
Broad coverage of concepts and methods of the physical and engineering sciences applied in biology and medicine, ranging from formalized mathematical theory through experimental science and technological development to practical clinical applications. (12)
Dr. Michael R. Neuman, Obstetrics & Gynecology, MetroHealth Medical Center, 2500 MetroHealth Dr., Cleveland, OH 44109
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Broadcasting, IEEE Trans.
Broadcast technology, including the production, distribution, transmission, and propagation aspects of broadcasting. (4)
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Circuits and Devices Magazine
Provides in-depth assessments of emerging technologies and their continued impact on the human-machine interface. Included are papers

and tutorials on VLSI; manufacturing technology; semiconductor processes; quantum electronics; digital and analog circuits; components and packaging. Also, book reviews, news and notes, conferences, workshops, seminars, and lectures. (6)

Ronald W. Waynant, Food and Drug Administration, Center for Devices and Radiological Health (CDRD), Electro-Optics Branch, HFZ-134, 1901 Chapman Rd., Rockville, MD 20857 301-443-2965

Circuits and Systems, Part I: Fundamental Theory and Applications; IEEE Trans.
Widely recognized forum for new results in electronic circuits and systems; system theory; discrete, IC, and VLSI circuit design; nonlinear circuits and systems; multidimensional circuits and systems; theory of analog and discrete-time filtering; graph theory; and large-scale systems and power networks. (12)

Circuits and Systems, Part II: Analog and Digital Signal Processing; IEEE Trans.
Analog and digital signal processing, including active, passive, switched-capacitor, and digital filters; nonlinear filters and signal-processing operators; new hardware structures and software algorithms for signal processing; video and image processing; and signal processing in higher dimensions. (12)

Wai-Kai Chen, Dept. of Electrical Engineering, University of Illinois at Chicago, Chicago, IL 60680 312-996-2462

Circuits and Systems for Video Technology, IEEE Trans.
Video A/D and D/A, display technology, image analysis and processing, video signal characterization and representation, video compression techniques and signal processing, multidimensional filters and transforms, analog video signal processing, neural networks for video applications, nonlinear video signal processing, video storage and retrieval, computer vision, packet video, high-speed real-time circuits, VLSI architecture and implementation for video technology, multiprocessor systems—hardware and software—video systems architecture, video quality assessment, and other video-technology-related topics. (6)

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Communications, IEEE Trans.
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Communications, Selected Areas in; IEEE J.
All telecommunications, including telephone, telegraphy, facsimile, and point-to-point television, by electromagnetic propagation, including radio; wire; aerial, underground, coaxial, and submarine cables; waveguides, communication satellites, and lasers; in marine, aeronautical, space, and fixed station services; repeaters, radio relaying, signal storage, and regeneration; telecommunication error detection and correction; multiplexing and carrier techniques; communication switching systems; data communications; and communication theory. (9)

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Components, Hybrids, and Manufacturing Technology, IEEE Trans.
Component parts, hybrid microelectronics, materials, packaging techniques, and manufacturing technology. (8)

Paul G. Slade, Westinghouse R&D, 1310 Beulah Rd., Pittsburgh, PA 15235-5098 412-256-1010

Computer-Aided Design of Integrated Circuits and Systems, IEEE Trans.
Methods, algorithms, and human-machine interfaces for physical and logical design, including: planning, synthesis, partitioning, modeling, simulation, layout, verification, testing, and documentation of integrated-circuit and systems designs of all complexities. Practical applications of aids resulting in producible analog, digital, optical, or microwave integrated circuits are emphasized. (12)

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Computer Applications in Power Magazine
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Ted G. Lewis, Oregon State University, Dept. of CS, Corvallis, OR 97331 503-737-5577

Computers, IEEE Trans.
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Consumer Electronics, IEEE Trans.
The design and manufacture of consumer electronics products, components, and related activities, particularly those used for entertainment, leisure, and educational purposes. (4)

Wayne C. Luplow, Zenith Electronics Corp., 1000 Milwaukee Ave., Glenview, IL 60025 312-391-7873

Control Systems Magazine
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Herbert Rauch, Lockheed 92-30/250, 3251 Hanover St., Palo Alto, CA 94304 415-424-2704

Control Systems Technology, Trans.
An archival journal bridging theory and practice and covering advances in control engineering. Control systems from analysis and design through simulation and hardware. (4)

Bruce Krogh, Dept. ECE, Carnegie Mellon University, Pittsburgh, PA 15213 412-268-2472

Design and Test of Computers Magazine
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Manuel A. d'Abreau, Intel Corp., M/S FM 3108, 1900 Prairie City Rd., Folsom, CA 95630

Dielectrics, IEEE Trans.
Electrical insulation common to the design and construction of components and equipment for use in electric and electronic circuits and distribution systems at all frequencies. (6)

Arend van Roggen, RD 2, Kennett Square, PA 19348 215-388-6909

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Electromagnetic Compatibility, IEEE Trans.
EMC standards; measurement technology; undesired sources; cable/grounding; filters/shielding; equipment EMC; systems EMC; antennas and propagation; spectrum utilization; electromagnetic pulses; lightning; radiation hazards; and Walsh functions. (4)
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Electron Device Letters
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John Brews, Dept. of Electrical and Computer Engineering, Room 230, Building 104, University of Arizona, Tucson, AZ 85721 602-621-8734

Electron Devices, IEEE Trans.
The theory, design, and performance of active electron and ion devices, solid-state devices, integrated electron devices, and energy sources. (12)
Renuka Jindal, AT&T Bell Labs, Room 15D-240, 67 Whippany Rd., Whippany, NJ 07981 201-386-5322

Electronic Materials, IEEE J.
Applications of semiconductors, magnetic alloys, insulators, and optical and display materials. (12)
Theodore C. Harman, MIT Lincoln Laboratory, Lexington, MA 02173 617-981-4418

Energy Conversion, IEEE Trans.
Research, development, design, application, construction, installation, and operation of electric power generating facilities (along with their conventional, nuclear, or renewable sources) for the safe, reliable, and economic generation of electrical energy for general industrial, commercial, public, and domestic consumption. (4)
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Engineering Management, IEEE Trans.
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A.S. Wald, Dept. of Anesthesiology, Columbia-Presbyterian Medical Center, 630 W. 168th St., New York, NY 10032 212-305-2164

Expert Magazine (Intelligent Systems and Their Applications)
Tutorial and survey articles on the current applications of intelligent systems, including databases, expert systems, and artificial intelligence. (6)
B. Chandrasekaran, Ohio State University, Computer and Information Sciences Dept., Room 228, Bolz Hall, 2036 Neil Ave., Columbus, OH 43210-1277

Fuzzy Systems, IEEE Trans.
Theory and application of fuzzy systems with emphasis on engineering systems and scientific applications.
James C. Bezdek, Dept. of Computer Sci., Univ. West Florida, Pensacola, FL 32514 904-474-2784

Geoscience and Remote Sensing, IEEE Trans
Theory, concepts, and techniques of science and engineering as applied to sensing the earth, oceans, atmosphere, and space; and the processing, interpretation, and dissemination of this information (6)
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Image Processing, IEEE Trans.
Signal-processing aspects of image processing, imaging systems, and image scanning, display, and printing. Includes theory, algorithms, and architectures for image coding, filtering, enhancement, restoration, segmentation, and motion estimation; image formation in tomography, radar, sonar, geophysics, astronomy, microscopy, and crystallography; image scanning, digital half-toning and display, and color reproduction. (4)
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Industrial Electronics, IEEE Trans.
Theory and applications of industrial electronics and control instrumentation science and engineering, including microprocessor control systems, high-power controls, process control, programmable controllers, numerical and program control systems, flow meters, and identification systems. (6)
James C. Hung, Dept. of Electrical and Computer Engineering, University of Tennessee, Knoxville, TN 37996 615-974-5420

Industry Applications, IEEE Trans.
The development and application of electric systems, apparatus, devices, and controls to the processes and equipment of industry and commerce; the promotion of safe, reliable, and economic installations; the encouragement of energy conservation; the creation of voluntary engineering standards and recommended practices (6)
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The fundamental nature of the communication process; transmission and utilization of information; coding and decoding of digital and analog communication transmissions; study of random interference and information-bearing signals; and the development of information-theoretic techniques in diverse areas, including communication systems, detection systems, pattern recognition, learning, and automata. (6)
Richard Blahut, IBM Corp., Bodle Hill Rd., Owego, NY 13827

Instrumentation and Measurement, IEEE Trans
.Measurements and instrumentation utilizing electrical and electronic techniques. (6)
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Knowledge and Data Engineering, IEEE Trans.
Artificial intelligence techniques, including speech, voice, graphics, images, and documents; knowledge and data engineering tools and techniques; parallel and distributed processing; real-time distributed processing; system architectures, integration, and modeling; database design, modeling, and management; query design, and implementation languages; distributed database control; statistical databases; algorithms for data and knowledge management; performance evaluation of algorithms and systems; data communications aspects; system applications and experience; knowledge-based and expert systems; and integrity, security, and fault tolerance. (6)
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Lightwave Technology, J.
All aspects of optical guided-wave science, technology, and engineering in the areas of fiber and cable technologies; active and passive guided-wave componentry (light sources, detectors, repeaters, switches, fiber sensors, etc.); integrated optics and optoelectronics; systems and subsystems; new applications; and unique field trials (12)
Donald Keck, Corning Glass Works, SP FR 29, Corning, NY 14831 607-974-3095

Magnetics, IEEE Trans.
Science and technology related to the basic physics of magnetism, magnetic materials, applied magnetics, magnetic devices, and basic and applied superconductivity. (6)
William Lord, Department of Electrical Engineering, Iowa State University, Ames, IA 50011 515- 294-3685

Medical Imaging, IEEE Trans.
Imaging of body organs, usually in situ, rather than microscopic biological entities; the associated equipment and techniques, such as instrumentation systems, transducers, computing hardware, and software. (4)
Gabor Herman, Hospital of Univ. Pennsylvania, Dept. Radiology, 3400 Spruce St., Philadelphia, PA 19104

Micro Magazine
Microprocessor technology; computer-aided design; system support software, interfacing techniques, chip design, and fabrication; personal computing; control hierarchies, architectures, applications and draft standards for hardware, software, and interconnections. (6)
Dante Del Corso, Politecnico di Torino, Dipart. di Electr., C. Duca degli Abruzzi, 24, Torino 10129, Italia

Microelectromechanical Systems, IEEE J.
Micromechanics, Microdynamics, Microelectromechanical Systems, MEMS: articles on small devices—from microns to millimeters; microfabrication techniques; microphenomena; microrobots; microbatteries, microbearings; and other microcomponents; theoretical, computational, modeling and control results; new materials and designs; tribology; microtelemanipulation; and applications such as biomedical engineering, optics, and fluidics. (4)
William Trimmer, Belle Mead Research Inc., 55 Riverview Terrace, Belle Mead, NJ 08502
908-359-0012

Microwave and Guided Wave, IEEE Letters
Published monthly with the purpose of providing fast publication of original and significant contributions relevant to all aspects of microwave/millimeter-wave technology. Emphasis is on devices, components, circuits, guided-wave structures, systems and applications covering the frequency spectrum from microwave and beyond, including submillimeter-waves and infrared. Publication time will be two months from the end of the month in which a contribution was received, provided the author responds immediately to all communications. Acknowledgment letters will not be sent to the authors. Galley proofs will be sent, but in the interest of fast publication, there may not be time to wait for their return. Errata will be published in the next issue if sent promptly. Lengths of the letters are expected to be no longer than two printed pages. (12)
Tatsuo Itoh, Dept. of Electrical and Computer Engineering, University of California, 66-147 A Engineering IV, 405 Hilgard Ave., Los Angeles, CA 90024 213-206-4820

Microwave Theory and Techniques, IEEE Trans
Microwave theory, techniques, and applications as they relate to components, devices, circuits, and systems involving the generation, transmission, and detection of microwaves. (12)
Stephen Maas, EE Dept., 56-125B Engineering IV, UCLA, Los Angeles, CA 90024
213-206-1668

Network Magazine (The Magazine of Computer Communications)
Network protocols and architecture; protocol design and validation; communications software; network control, signaling, and management; network implementation (LAN, MAN, WAN); and micro-to-host communications. (6)
Warren S. Gifford, Bellcore, 331 Newman Springs Rd., Room 1C401, Red Bank, NJ 07701 201-758-2200

Networking IEEE/ACM Trans.
Network architecture and design, communication protocols, network software, network technologies, network software, network technologies, network services and applications, and network operations and management. (6)
James Kurose, Dept. Comp. & Info Sciences, Univ. Massachusetts, Amherst, MA 01003
413-545-1585

Neural Networks, IEEE Trans.
High-quality papers in the theory, design, and application of neural networks, ranging from software to hardware. Emphasis will be given to artificial neural networks. Readers are encouraged to submit manuscripts that disclose significant technical achievements, indicate exploratory developments, or present significant applications for neural networks. This Transactions contains a Letters section intended to serve as a vehicle for rapid publication of new, significant, and timely research results. The Letters section also includes information of current interest, and comments and rebuttals in connection with published papers (6)
Robert Marks, Dept. of Electrical Engineering, University of Washington, Seattle, WA 98195
206-543-6990

Nuclear Science, IEEE Trans.
All aspects of the theory and applications of nuclear science and engineering, including instrumentation for the detection and measurement of ionizing radiation; particle accelerators and their controls; nuclear medicine and its application; effects of radiation on materials, components, and systems; reactor instrumentation and controls; and measurement of radiation in space. (6)
Dick A. Mack, 600 Lockewood Lane, Santa Cruz, CA 95066 408-438-0200

Oceanic Engineering, IEEE J.
Bayes procedures; buried-object detection; dielectric measurements; Doppler measurements; geomagnetism; sea floor; sea ice; sea measurements; sea surface electromagnetic scattering; seismology; sonar; acoustic tomography; underwater acoustics; and underwater radio communication. (4)
William Carey, Naval Underwater Systems Ctr., Code 302, New London, CT 06320
203-440-6699

Parallel and Distributed Systems, IEEE Trans.
Architectures—design, analysis, and implementation of multiprocessor systems (including multiprocessors, multicomputers, and networks); impact of VLSI on system design; interprocessor communications. Software—parallel languages and compilers; scheduling and task partitioning; databases, operating systems, and programming environments for multiple-processor systems. Algorithms and applications—models of computation; analysis and design of parallel/distributed algorithms; application studies resulting in better multiple-processor systems. Other issues—performance measurements, evaluation, modeling and simulation of multiple-processor systems; real-time, reliability and fault-tolerance issues; and conversion of software from sequential to parallel forms. (6)
Tse-Yun Feng, Dept. of ECE, 121 Engineering East Building, Pennsylvania State University, University Park, PA 16802 814-863-1469

Parallel and Distributed Technology Magazine
Advances in parallel and distributed computing technology, specifics on unique features and applications. Computational models, distributed databases, high-speed networks, numerical algorithms, parallel and distributed computer architectures, and supercomputing.
Michael Quinn, Oregon State Univ., Dept. of Computer Sci., Corvallis, OR 97331
503-737-5572

Pattern Analysis and Machine Intelligence, IEEE Trans.
Statistical and structural pattern recognition; image analysis; computational models of vision; computer vision systems; enhancement, restoration, segmentation, feature extraction, shape and texture analysis; applications of pattern analysis in medicine, industry, government, and the arts and sciences; artificial intelligence, knowledge representation, logical and probabilistic inference, learning, speech recognition, character and text recognition, syntactic and semantic processing, understanding natural language, expert systems, and specialized architectures for such processing. (12)
Anil Jain, Dept. of Computer Science, A-726 Wells Hall, Michigan State University, East Lansing, MI 48824 517-353-5150

Photonics Technology, IEEE Letters
Rapid publication of original research relevant to photonics technology. This expanding field emphasizes laser and electro-optic technology, laser physics and systems, applications, and photonic/lightwave components and applications. The journal offers short, archival publication with minimal delay. (12)
Paul W. Shumate, Bellcore 2Q-186, 445 South St., Morristown, NJ 07960 201-829-4600

Plasma Science, IEEE Trans.
Plasma science and engineering, including: magnetofluid dynamics and thermionics; plasma dynamics; gaseous electronics and arc technology; controlled thermonuclear fusion; electron, ion, and plasma sources; space plasmas; high-current relativistic electron beams; laser-plasma interactions; diagnostics; plasma chemistry and colloidal and solid-state plasmas. (6)
Steven J. Gitomer, Office of Arms Control, U.S. Dept. of Energy, DP-5.2, Forrestal Building, 1000 Independence Ave., S.W., Washington, DC 20585

Power Delivery, IEEE Trans.
Research, development, design, application, construction, the installation and operation of apparatus, equipment, structures, materials, and systems for the safe, reliable, and economic delivery and control of electric energy for general industrial, commercial, public, and domestic consumption. (4)
Harold Gold, 1037 North Primrose, Rialto, CA 92376 714-875-8117 For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331 908-562-3881

Power Electronics, IEEE Trans.
Fundamental technologies used in the control and conversion of electric power. Topics include dc-to-dc converter design, direct off-line switching power supplies, inverters, controlled rectifiers, control techniques, modeling, analysis and simulation techniques, the application of power circuit components (power semiconductors, magnetics, capacitors), and thermal performance of electronic power systems. (4)
Richard Hoft, Electrical and Computer Engineering Dept., University of Missouri, 223 Electrical Engineering, Columbia, MO 65211
314-882-3491

Power Engineering Review
Electric power system engineering; includes one-page summaries of all papers accepted for publication in Energy Conversion, Power Delivery, and Power Systems. Also includes the Power Engineering Society Newsletter, selected prize papers, high-interest papers, and other articles of technical interest. (12)
C.J. Essel, 5969 W. 76th St., Los Angeles, CA 90045 213-645-3380

Power Systems, IEEE Trans.
Requirements, planning, analysis, reliability, operation, and economics of electrical generating, transmission, and distribution systems for indus-

trial, commercial, public, and domestic consumption. (4)

Harold Gold, 1037 North Primrose, Rialto, CA 92376 714-875-8117 For information on manuscript submission: Nancy Heitmann, Society Special Services of Technical Activities Dept., IEEE Service Center, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855-1331 908-562-3881

Professional Communication, IEEE Trans.
The study, development, improvement, and promotion of techniques for preparing, organizing for use, processing, editing, collecting, conserving, and disseminating any form of information in the electrical and electronics fields. (4)

Dr. Scott Sanders, Dept. of English Language and Literature, University of New Mexico, Albuquerque, NM 87131 505-277-4437

Quantum Electronics, IEEE J.
Generation, amplification, modulation, detection, waveguiding, or techniques and effects that can affect the propagation characteristics of coherent electromagnetic radiation having submillimeter and shorter wavelengths. (12)

Steven R.J. Brueck, Center for High Technology Materials, University of New Mexico, EECE Bldg., Rm. 125, Albuquerque, NM 87131 505-277-6033

Rehabilitation Engineering, IEEE Trans.
Rehabilitation aspects of biomedical engineering, including functional electrical stimulation, acoustic dynamics, human performance measurement and analysis, nerve stimulation, electromyography, motor control and stimulation, and hardware and software applications for rehabilitation engineering and assistive devices. (4)

Charles J. Robinson, Univ. Sch. Health & Rehabilitation, 107B Pennsylvania Hall, Univ. Pittsburgh, Pittsburgh, PA 15216 412-624- 8945

Reliability, IEEE Trans.
Principles and practices of reliability, maintainability, and product liability pertaining to electrical and electronic equipment. (5)

Dr. Michael Pecht, Mechanical Engineering Dept., University of Maryland, College Park, MD 20742 301-405-5278

Robotics and Automation, IEEE Trans.
Theory and applications in robot dynamics and control; simulation of robots and manufacturing systems; robot languages; robotic vision and other sensory interfaces; manipulator design; robot locomotion; management of multirobot systems; geometric modeling, other computer-aided design techniques; robot manufacturing; motion planning, task planning, and expert systems in robotics and automation; hardware and software implementation of robotic systems. (6)

Russell H. Taylor, Manufacturing Research Dept., IBM T.J. Watson Res. Center, Box 704, Yorktown Heights, N.Y. 10598 914-784-7796

Semiconductor Manufacturing, IEEE Trans.
Process control techniques; process modeling, simulation, measurements, diagnostics; defect characterization and control; yield analysis and modeling; product design for manufacturability, reliability; product transfer from development to manufacturing; factory design, simulation; automation: models, algorithms, equipment interfaces, etc.; equipment design: modeling and simulation; production control and scheduling; operations management: training, incentives, productivity measures; standards: materials, processes; computer integration: computer-controlled equipment and facilities; and the application of AI and expert systems. (4)

Costas Spanos, 568 Cory Hall, University of California, Berkeley, CA 94720 510-643-6776

Signal Processing, IEEE Trans.
Transmission, recording, reproduction, processing, and measurement of speech and other signals by digital, electronic, electrical, acoustic, mechanical, and optical means; the components and systems to accomplish these and related aims; and the environmental, psychological, and physiological factors of these technologies. (12)

Pierce Wheeler, 435 Rt. 24, Chester, NJ 07930 908-879-5746

Signal Processing Magazine
Acoustics, including digital audio, underwater signal processing, and electroacoustics; speech, including speech transmission and coding; enhancement and noise reduction; analysis and reconstruction; synthesis; recognition; production/synthesis; performance evaluation; signal processing, one-dimensional and multidimensional digital signal processing, including discrete Fourier and other transforms; nonlinear analysis; spectral analysis; signal and system identification; filter design and applications; applications to echo cancellation, aids for the handicapped, and radar; image processing; sensor array processing; multidimensional processing; VLSI; and hardware implementations. (4)

Jack Deller, EE Dept., 258 Engineering Building, Michigan State University, East Lansing, MI 48824-1226 517-353-8840

Software Engineering, IEEE Trans.
Specification, development, management, test, maintenance, and documentation of computer software. (12)

Nancy G. Leveson, Dept. Info. and Comp. Sci., Univ. California, Irvine, CA 92717 714-856-5517

Software Magazine
Tutorials and surveys on current techniques and new products in software design and development. Focuses on such topics as software tools, measuring program reliability, designing software tests, PCs as programming workstations, localization of bugs, and making programs readable. (6)

Carl K. Chang, University of Illinois, Dept. EECS, M/C 154, Chicago, IL 60680 312-996-4860

Solid-State Circuits, IEEE J.
Analysis, design, and performance of solid-state circuits; transistors; diodes; bulk-effect and magnetic devices; digital; analog; microwave; optoelectronic; integrated circuits; and large-scale integration. (12)

Asad A. Abidi, EE Dept., Room 56-125B Engineering IV, Univ. California, Los Angeles, CA 90024-1594 310-825-9490

Speech and Audio Processing, Trans.
Speech analysis, synthesis, coding speech recognition, speaker recognition, language modeling, speech production and perception, speech enhancement. In audio, transducers, room acoustics, active sound control, human audition, analysis/synthesis/coding of music, and consumer audio. (4)

Dan Kahn, Bell Comm Res., Room 2E-268, 445 South St., Morristown, NJ 07962-1910 201-829-4522

Systems, Man, and Cybernetics, IEEE Trans.
Large-scale systems, theory and applications; optimization; decision analysis; problem definition; modeling; simulation; testing; evaluation; foundations of cybernetics; pattern recognition; adaptive and learning systems; and biocybernetics. (6)

Andrew P. Sage, School of Information Technology & Engineering, George Mason University, 4400 University Dr., Fairfax, VA 22030 703-993-1500

Technology and Society Magazine
Impact of technology (as embodied by the fields of interest of IEEE) on society, including both positive and negative effects; the impact of society on the engineering profession, the history of the societal aspects of electrotechnology, and professional, social, and economic responsibility in the practice of engineering and its related technology. (4)

Leon Zelby, Dept. of EE, 202 W. Boyd, University of Oklahoma, Norman, OK 73019 405-325-4290

Ultrasonics, Ferroelectrics and Frequency Control, IEEE Trans.
Acoustic holography and imaging; acousto-optic interactions; biological and medical applications; filters and resonators; industrial applications; nondestructive evaluation; physical acoustics; piezoelectric and magnetostrictive materials; surface-acoustic-wave-based systems; surface-acoustic-wave devices; and underwater sound. (6)

William D. O'Brien, Bioacoustics Research Lab, Dept. of Electrical & Computer Engineering, University of Illinois, 1406 West Green St., Urbana, IL 61801 217-333-2407

Vehicular Technology, IEEE Trans.
Land, airborne, and maritime mobile services; portable or hand-carried and citizen's communications services, when used as an adjunct to a vehicular system; vehicular electrotechnology, equipment, and systems ordinarily identified with the automotive industry. (4)

Sang B. Rhee, AT&T Bell Laboratories, Room 2F-203, Whippany Rd., Whippany, NJ 07981 201-386-6796

Very Large Scale Integration (VLSI) Systems, IEEE Trans.
Systems specifications, design and partitioning, high-performance computing and communication systems, neural networks, wafer-scale integration, and multichip module systems and their applications. (4)

Steve Kang, Coordinated Science Lab, Univ. Illinois, 1101 West Springfield, Urbana, IL 61801

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The following listings of interest to IEEE members have been placed by educational, government, and industrial organizations as well as by individuals seeking positions. To respond, apply in writing to the address given or to the box number listed in care of *Spectrum* Magazine, Classified Employment Opportunities Department, 345 E. 47th St., New York, N.Y. 10017.

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IEEE encourages employers to offer salaries that are competitive, but occasionally a salary may be offered that is significantly below currently acceptable levels. In such cases the reader may wish to inquire of the employer whether extenuating circumstances apply.

Academic Positions Open

Trinity College, Hartford, Connecticut - Assistant Professorship in Electrical Engineering. Trinity College seeks applicants, with the Ph.D. in Electrical Engineering and primary expertise in semiconductor devices and materials, to fill a three-year assistant professorship in the Department of Engineering and Computer Science (ECS) starting in Fall, 1993. We especially seek applications from women and minority candidates. Experience in optoelectronics and/or VLSI design is highly desirable. Familiarity with Computer Engineering and Computer Science fundamentals will strengthen the application. The ECS Department is located in the new Mathematics, Computing, and Engineering Center that houses laboratories for instruction and research in solid mechanics, materials science, fluid mech anics, digital and analog electronics, and electrophysiology. A campus-wide LAN links VAX, SUN, HP/Apollo, PC, and Macintosh computers in offices and laboratories to the Internet. A HP/Apollo network offers a full suite of Mentor Graphics and Seattle Silicon CAD tools as well as access to MOSIS. Send curriculum vita and names of three references to Dr. David J. Ahlgren, Chair, ECS Department, Trinity College, Hartford, CT 06106. Applications accepted until February 15, 1992. Trinity College is an AA/EO employer.

The Bradley Department of Electrical Engineering of Virginia Polytechnic Institute and State University (Virginia Tech) invites applications for tenure track faculty positions at all levels. Needs are in the areas of: (1) thin film devices, including high temperature superconductors and optical devices, and epitaxial device analysis, design, fabrication, and processing; (2) analog circuitry with emphasis on analog VLSI design, analog signal processing, and high frequency techniques. Applicants must have an earned doctorate in Electrical Engineering, be interested in undergraduate and graduate teaching, and be willing to secure research sponsorship. A background of research leadership and international prominence is expected of any senior level applicant. Virginia Tech is Virginia's land grant university offering degrees through the Ph.D. Send complete resume with references and employment/citizenship status to: Prof. Gary S. Brown, Search Committee, Bradley Department of Electrical Engineering, Virginia Tech, Blacksburg, VA 24061-0111. Applications will be accepted until February 15, 1993, or until suitable candidates are selected. Virginia Tech is an Equal Opportunity/Affirmative Action Employer and welcomes applications from minorities and women.

Endowed Chair. Texas A&M University invites nominations and applications for an endowed faculty position in the Electrical Engineering Department in the area of Computer Engineering. The endowment is approximately $2,000,000. Candidates should have outstanding personal and professional qualifications, including international recognition for research contributions. Individuals from academic, industrial, and government research backgrounds are invited to apply. The successful candidate will be expected to provide leadership in both research and teaching and to participate in the development and coordination of programs in the Computer Engineering Group within the Department and in cooperation with the Computer Science Department. The group presently consists of approximately 10 faculty members. The Electrical Engineering Department has about 1200 undergraduate students, 450 graduate students, and a faculty of 49. The active areas of research include digital and analog microelectronics, electronic and magnetic materials and devices, electromagnetics, microwave engineering, computer engineering, electro-optics, controls, telecommunications, and power systems and power electronics. The closing date for this announcement is December 31, 1992. Nominations and applications should be submitted to Dr. Henry F. Taylor, Chairman, Electrical Engineering Chair Search Committee, Department of Electrical Engineering, Texas A&M University, College Station, Texas 77843, (409) 845-7441. Texas A&M University of an affirmative action equal opportunity employer.

The University of Florida, Department of Electrical Engineering, is seeking individuals to fill three junior faculty positions in the following areas: solid-state electronic circuits, systems and controls, communications, and computer engineering/digital signal processing. The positions are tenure track beginning in the Fall of 1993. Candidates are required to have a Ph.D. in an area related to the field. Potential faculty members are expected to develop a program of funded research in the area of their expertise as well as teach in that area. The University of Florida is an Affirmative Action Employer and women and minorities are encouraged to apply. According to Florida law, applications and meetings regarding applications are open to the public upon request. Please send application to Dr. M.A. Uman, Chairman, Department of Electrical Engineering, 216 Larsen Hall, University of Florida, Gainesville, Florida 32611. Applications must be received by February 1, 1993.

The Johns Hopkins University, Department of Electrical and Computer Engineering, invites applications for tenure-track faculty positions at the assistant or associate professor level in the areas of computer engineering, communications, and signal/image processing. Candidates for associate professor appointments are expected to have significant research records. Candidates for assistant professor appointments are expected to show strong research potential. Applicants should send resumes, including names of at least three references, to Search Committee, Department of Electrical and Computer Engineering, The Johns Hopkins University, Baltimore, MD 21218-2868. Resumes may also be faxed to (410) 516-5566. The Johns Hopkins University is an equal opportunity/affirmative action employer.

San Jose State University, Electrical Engineering Department - Applications are invited for tenure-track faculty positions. Assistant Professor applicants are particularly encouraged to apply. Positions are available in microelectronic VLSI/ULSI circuit design, semiconductor devices and technologies; circuits, systems and computer communications networks; computer and multiprocessor design, microprocessor applications. Earned doctorate in Electrical Engineering is required. Positions are limited to U.S. citizens or permanent residents. Research, consulting and summer employment opportunities are available. The University is the oldest and one of the largest in the California State University System. It is located at the southern end of San Francisco Bay in the heart of Silicon Valley. Resume and names and addresses of three references should be submitted to Dr. Ray R. Chen, Chair, Department of Electrical Engineering, San Jose State University, San Jose, CA 95192-0084. San Jose State University is an equal opportunity/affirmative action/Title IX employer. Women and minorities are especially encouraged to apply.

Electrical Engineering: The Department of Electrical Engineering at Memphis State University is now accepting applications for tenure-track faculty positions. Preference will be given to applicants for the Assistant or Associate Professor level. Applicants with research specializations in computer engineering, biomedical engineering, communications, power or electro-optics are preferred. Candidates should be available for employment by August 20, 1993. Research experience and potential for securing funded research will be important considerations in candidate selection. An earned doctorate in electrical engineering or related area is required. Interested applicants should send resumes with names, addresses, and telephone numbers of three references to: Dr. Carl E. Halford, Department of Electrical Engineering, Memphis State University, Memphis, TN 38152. Closing date for applications is January 29, 1993, with initial screening to begin at that time. However, if needed, applications will be reviewed until positions are filled. Equal opportunity, affirmative action employer. Successful candidates must meet Immigration Reform Act criteria.

University of Illinois at Chicago. Instructorships and tenure-track faculty positions in electrical engineering and computer science at both the junior and senior levels are available. Rank and salary commensurate with qualifications. An earned Doctorate in EE or CS must be completed by date of appointment, but not for the instructorships. Demonstrated teaching and research abilities are highly desirable. For full consideration, please send resume, list of publications, and the names of at least three references by March 30, 1993, to Dr. Wai-Kai Chen, Head, Department of Electrical Engineering and Computer Science (M/C 154), University of Illinois at Chicago, P.O. Box 4348, Chicago, Illinois 60680. The University of Illinois is an Affirmative Action/Equal Opportunity Employer.

The Center for Advanced Computer Studies. The Center is seeking highly qualified candidates for tenure track faculty positions in Computer Science and Computer Engineering. Three openings are available: one at each professorial rank beginning Fall 1993. Candidates must hold PhDs in the field and have strong research potential. Senior candidates must have established research and publication records. Consideration will be given to all qualified candidates, but preference areas of interest are: software engineering, programming languages, operating systems, database systems, image processing, computer architecture, and theoretical computer science. The Center conducts programs leading to the MS/PhD degrees in Computer Science and Computer Engineering. These programs currently enroll more than 250 students, including over 100 PhD students. A number of PhD fellowships and assistantships are available, with stipends of up to $18,000 per year, renewable for a maximum of four years. Typical faculty teaching load is two courses per year and a continuing research seminar. Substantial State Educational Fund monies are available to establish research programs. The University is located in Acadiana, about 120 miles west of New Orleans. Send resumes to: Dr. Michael C. Mulder, Director, The Center for Advanced Computer Studies, University of Southwestern Louisiana, P.O. Box 44330, Lafayette, LA 70504. Applications will be considered beginning 1 January 1993 until all positions are filled. The University of Southwestern Louisiana is an affirmative action/equal opportunity employer.

University of California, Davis - Faculty Positions in Electrical and Computer Engineering. The Department of Electrical and Computer Engineering at UC Davis invites applications for a tenure track faculty position at the Assistant Professor level. Applicants are sought in the following two areas: (1) computer engineering with speciality in embedded computing systems, hardware/software co-design, and real time operating systems; and (2) optoelectronic devices with particular emphasis in experimental research on compound semiconductor optoelectronic devices and their fabrication. The department, with 34 faculty members and 140 full-time graduate students, is experiencing rapid growth. We have exceptional teaching and research facilities and are preparing to move into a large, new building which is currently in the final stages of construction. Salary and benefits are extremely attractive. Davis is a pleasant, family-oriented community near Sacramento, within easy driving distance to Silicon Valley, the Lawrence Livermore National Laboratory, San Francisco, the Pacific Ocean, and the Sierra Nevada Mountains. We are seeking individuals with strong records in research, with ambitious plans and evidence of great promise. All faculty are expected to have a strong commitment to teaching at all degree levels, and to demonstrate the ability to attract significant research support. The positions require a Ph.D. degree or equivalent, and are open until filled; but in order to assure consideration, applications should be received by April 1, 1993. Send a resume and the names of at least three references to: Professor S. Louis Hakimi, Chair, Attention: Faculty Search Committee, Department of Electrical Engineering and Computer Science, University of California, Davis, CA 95616. The University of California, Davis, is an equal opportunity/affirmative action employer.

Communication Systems at Arizona State University. The Department of Electrical Engineering is seeking a faculty member (Assistant, Associate, or Full Professor, tenure-track) in the area of Communication Systems. Senior-level applicants having expertise in Digital Communication Theory, Optical Communications, Spread Spectrum Communications, Modulation Theory, or Information Theory arâe particularly encouraged. Applicants must hold an earned doctorate in Electrical Engineering or a related discipline, have a distinguished record of research and teaching accomplishments, and show evidence of leadership in sponsored research and professional service. Arizona State University is the fifth largest U.S. university, with approximately 30,000 undergraduate and 12,000 graduate students. The College of Engineering and Applied Sciences at ASU is established among the leading up-and-coming engineering graduate schools. The Department of Electrical Engineering has approximately 850 undergraduate and 470 graduate students, and research expenditures of $3M per year. Communication Systems engineering at ASU benefits from a strong base of telecommunication industry in the Phoenix area and active programs in related disciplines within the Department of Electrical Engineering and the Telecommunications Research Center. Applicants should send a letter of application, a resume with publication list, and the addresses and telephone numbers of three references to: Faculty Search Committee; Department of Electrical Engineering; Arizona State University; Tempe, AZ 85287-5706. The first application deadline is 15 January 1993; thereafter, applications will be reviewed on the 15th of each month until the position is filled. Arizona State University is an Equal Opportunity Employer. The Department encourages diversity among its applicants.

Computer Engineering and Design, Control Systems and Design - The Department of Electrical Engineering of Western Michigan University invites applications for several anticipated tenure-track faculty positions at the Assistant/Associate/Full Professor levels. Preferred applicants must 1) have an earned PhD in Computer Engineering, Electrical Engineering, or the equivalent, 2) specialize in computer architecture, logic design, digital electronics and real-time embedded systems, and 3) have industrial-level design experience. Responsibilities include graduate and undergraduate teaching, curricular leadership, and research. Senior faculty applicants should demonstrate experience in applied engineering design. Western Michigan University is located in Kalamazoo, Michigan and has approximately 26,000 students; it is one of the state's five graduate intensive universities and is designated a Carnegie Doctoral I university. The Department offers two EAC/ABET accredited undergraduate degrees (Computer Systems Engineering and Electrical Engineering) and a growing graduate program. We are especially looking for experienced computer engineers and control engineers who enjoy teaching and would like to participate in building a design-oriented graduate program in computer and systems engineering. Please send a detailed resume and the names of three references to: Dr. Thomas F. Piatkowski, Chair, Department of Electrical Engineering, Western Michigan University, Kalamazoo, MI 49008-5066 or piatkowski@gw.wmich.edu. Applications will be accepted until the position is filled; we hope to fill some of the positions for January, 1993. Western Michigan University is an equal opportunity/affirmative action employer.

Senior and junior faculty positions are available in the Department of Computer Science, Texas A&M University, College Station, Texas. Areas of interest include, but are not limited to, macro and micro computer architecture, VLSI CAD, testing and timing, fault-tolerant and reliable computing, software engineering, programming languages, real-time computing, computer networks and database. The Department is currently the home to twenty-five tenure track faculty including three NSF PYI/NYI recipients. Also, the Department is a recent recipient of a sizable NSF infrastructure grant. The excellent research facilities include a 64 node NCUBE, a 2000 node MASPAR, Sequent Balance, numerous SPARC4, RS 6000 Silicon Graphics, Symbolics, NeXT and Real Time System Work Stations as well as access to the University's CRAY YMP2/116, IBM 3090/200E, Amdahl 5860, and more. Texas A&M University and the Department are committed to building the very best quality computer science and computer engineering programs. Departmental research activities span a broad range of areas including computer and fault tolerant systems, intelligent systems, computer networks, parallel computation, robotics and manufacturing, software technology and systems, and theoretical computer science, all of which provide for strong research interaction. College Station is located less than two hours driving distance from both Austin and Houston. Also it is well connected by air with Dallas and Houston. Consistently, independent surveys have ranked this area as one of the top places within the entire country for overall living. Applications and inquiries should be directed to: Chairman, Search Committee, Dept. of Computer Science, Texas A&M University, College Station, TX 77843-3112, (409) 845-5534. Texas A&M University is an affirmative action, equal opportunity employer.

Electrical Engineering: The University of Portland seeks a faculty member in the area of microelectronics and VLSI circuit design. Ph.D. in Electrical Engineering is required, dedication to excellence in teaching is essential. Duties include teaching undergraduate and graduate courses, laboratory development, and scholarship activities in the area of specialization. Tenure track position, Assistant or Associate rank. Send resume and names of at least three references to: EE Search Committee, School of Engineering, University of Portland, 5000 N. Williamette Blvd., Portland, OR 97203. (503) 283-7314. An affirmative action/equal opportunity employer.

University of Massachusetts - Computer Engineering. The Department of Electrical and Computer Engineering at the University of Massachusetts at Amherst invites applications for a tenure-track faculty position in the area of computer systems engineering. Rank and salary will be commensurate with qualifications: junior-level applicants are expected to show promise of research excellence, while applicants for a senior rank must have a substantial record of high-quality research. The Computer Systems Engineering group in the ECE department consists at present of eight faculty with research interests including computer architecture, VLSI, computer-aided design real-time systems, computer networks, computer arithmetic, computer graphics, testing, and fault-tolerant computing. Close ties are also maintained with the Computer Science department, which has strengths in artificial intelligence, computer theory, and software systems. Send a resume and names of at least three references to Head, Department of Electrical and Computer Engineering, University of Massachusetts, Amherst, MA 01003. Applications should be received by March 1, 1993, to ensure full consideration. The University of Massachusetts is an Affirmative Action/Equal Opportunity Employer.

Electrical Engineering Faculty Position: Penn State Erie, The Behrend College. Applications are invited for a tenure-track faculty position at the Assistant Professor level to teach baccalaureate engineering courses starting Fall Semester 1993. Ph.D. degree in Electrical Engineering or closely related field required. Preference will be given to individuals with previous teaching experience and interests in signal processing, with an emphasis on image processing and image interpretation, e.g., computer vision, multidimensional pattern recognition, or neural-net computing. Applicants should have an interest in undergraduate teaching, the ability to develop a research program at Penn State-Behrend, and the desire to work with faculty and administration on further development of a new engineering program. Penn State-Behrend is a 4-year, primarily undergraduate institution within the 22-campus Penn State system, and is one of only two Penn State Colleges other than University Park. Application deadline is February 15, 1993 or until position is filled. Send complete resume, transcripts and the names of three references to Dr. R. Progelhof, Director; School of Engineering and Engineering Technology; Department EE-1, Penn State Erie; Erie, PA 16563-0203. An Affirmative Action/Equal Opportunity Employer. Women and minorities encouraged to apply.

Delft University of Technology (Netherlands) Faculty of Electrical Engineering announces a vacant chair in Telecommunication Technology. The research area of the laboratory in which the appointed full professor will be working is the technology and the development of components for application in telecommunication systems, including remote sensing and navigation systems. The laboratory has facilities for simulation, fabrication and characterization of optoelectronic and microwave devices. The Laboratory participates in the research program of the Delft Institute for Microelectronics and Submicron Technology (DIMES) and the graduate program of the Advanced School of Electrical Engineering of the Delft University (ASEE). The professor is directly responsible for research in telecommunication technology, in particular directed towards the development and application of planar optoelectronic and microwave circuits for broadband telecommunication systems. He/she is expected to supervise the education in his/her speciality and to contribute actively by giving lectures on the subject of planar optoelectronic and microwave devices, and fibre communication technology. In addition to his/her own research work, the successful candidate will lead the scientific research efforts of other members of the laboratory, consisting of staff and students. The appointee must have recognized abilities and practical experience in the field of III-V semiconductors or optoelectronics, as is evidenced by a Ph.D. thesis and/or publications in internationally oriented journals in this research field. He/she is expected to promote collaboration with other research groups within the University, engaged in telecommunications, electronics and solid state physics. Send nominations or applications (including a C.V. and a list of publications) in confidence to: the Dean of the Faculty of Electrical Engineering, Prof.dr.ir. J. Davidse, P.O. Box 5031, 2600 GA Delft, the Netherlands, quoting vacancy No ET9212.

The Department of Electrical Engineering and Computer Engineering invites applications for several anticipated tenure-track faculty positions. Applicants at all ranks will be considered. Starting dates are negotiable with preference given for fall 1993. Primary needs are for specialization in the areas of communications, signal processing, controls, computer networks, distributed computing, data communications, microelectronics and VLSI design. Responsibilities include teaching, research and outreach. Salary

CLASSIFIED EMPLOYMENT OPPORTUNITIES

and rank are commensurate with qualifications and experience. Requirements include a doctorate degree with a demonstrated potential for success in research and a commitment to teaching. Applicants should send a resume with a statement of teaching, research, and outreach interests, as well as a list of at least three (3) references to: Chairman Faculty Search Committee, Department of Electrical Engineering and Computer Engineering, Iowa State University, Ames, Iowa 50011. Iowa State University is an Equal Opportunity/Affirmative Action Employer.

Head, Electrical and Computer Engineering. The University of Southwestern Louisiana invites nominations and applications for the position of Head. Screening will begin immediately and will continue until the position is filled. Qualifications include a Ph.D. in Electrical Engineering, a demonstrated record in research and teaching, and superior administrative capability. The position is at the rank of Full Professor. Candidates must be U.S. citizens. The Department of Electrical and Computer Engineering is one of seven departments in the College of Engineering. The Department has 14 faculty and offers the Bachelor of Science degree in Electrical Engineering and is the lead department in the interdisciplinary Master of Science in Telecommunications. The M.S. and Ph.D. in Computer Engineering are offered through the Center for Advanced Computer Studies. One focus of the Department is to extend the M.S. in Telecommunications to the Ph.D. level. The applicant should send a resume and names and telephone numbers for three references to: EECE Department Head Search Committee, USL P.O. Box 43890, Lafayette, LA 70504. USL is an Equal Opportunity Employer.

Stanford University: The Dept. of Mechanical Engineering, Design Division, invites applications for a tenure-track appointment at the Assistant Professorship level. The successful candidate will have outstanding research credentials in a design or manufacturing-related area such as concurrent engineering, design for manufacturability, rapid-prototyping or microfabrication processes. Related industrial experience is desired and an ability to forge connections with industry is expected. As a member of the Design Division, the successful candidate will also be expected to demonstrate a commitment to innovative design education. Stanford is an affirmative action employer, and applications from qualified women or minorities are encouraged. Please send a letter of introduction, resume and exemplary material to Professor Mark Cutkosky, Design Division, Mechanical Engineering Dept., Stanford University, Stanford, CA 94305-4021.

Georgia Institute of Technology. The School of Electrical Engineering seeks applicants for tenure track faculty positions at all levels. PhD in EE, or equivalent, and clear potential for distinguished performance in teaching and research are required. Areas of special need include senior faculty in computer engineering, telecommunications and experimental microelectronics. Resumes and statements of interest should be addressed to: Director, School of Electrical Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0250. Immigration status of non-US citizens should be indicated. Georgia Tech is an equal opportunity/affirmative action employer.

Georgia Southern University - The Department of Mathematics and Computer Science invites applications for a tenure-track position as either an Assistant or Associate Professor starting September 1, 1993. Requirements include a Ph.D. in Computer Science or closely related field with training/experience in more than one of the following four areas: Operating Systems, Parallel and Distributed Systems, Networking, and Data Communications. Candidates must also provide evidence of dedication to outstanding teaching. Duties include teaching graduate and undergraduate courses in computer science and supervision of research projects for M.S. degree candidates concentrating in computer science. Qualified applicants should send a letter of application, curriculum vitae, unofficial transcripts of all college work, and three letters of recommendation by February 15, 1993. The letter of application and/or vitae must specifically address all requirements listed above. Send to Dr. John A. Rafter, Landrum Box 8093, Georgia Southern University, Statesboro, GA 30460-8093. The names of applicants and nominees, resumes, and other general non-evaluative information are subject to public inspection under the Georgia Open Records Act. Georgia Southern University is an Affirmative Action/Equal Opportunity Institution.

The Department of Electrical and Computer Engineering invites applications for a tenure-track position. We are primarily interested in candidates whose areas of specialization are computer architecture, software engineering, optical computing, and electromagnetic fields. Applicants must have a doctoral degree in Electrical Engineering, Computer Engineering, Computer Science, or related fields. Preference will be given to candidates at the Assistant Professor level, but candidates at all levels will be considered. Especially strong senior candidates in optical computing and closely related areas are encouraged to apply for the Hudson Moore Chair. Review of applications will begin on January 1, 1993, although all applications postmarked before March 1, 1993 are eligible for consideration. Earlier applications will receive first consideration. Appointment can begin as early as August, 1993. The University of Colorado at Boulder has a strong institutional commitment to the principle of diversity. In that spirit, we are particularly interested in receiving applications from a broad spectrum of people, including women, members of ethnic minorities, and disabled individuals. Applications should be sent to Prof. William M. Waite, Chairman, Dept. of Electrical and Computer Engineering, University of Colorado, Campus Box 425, Boulder, CO 80309-0425.

Stanford University, Department of Aeronautics and Astronautics, seeks an outstanding person committed to teaching and research for appointment as Assistant Professor (tenure track) in the field of Optimal Control or Astrodynamics. Candidates are expected to have a solid background in dynamics, classical and modern control theory, and flight mechanics of aircraft and spacecraft. In addition, the candidates should have specialized knowledge in either orbit mechanics or optimal/robust control of aerospace systems. Stanford is an Affirmative Action employer and welcomes applications from women and minority candidates. Applications should be sent to: Professor J. David Powell, Aeronautics and Astronautics, Durand Building, Stanford University, Stanford, CA 94305.

Electrical Engineering: The University of Dayton invites applications for a tenure-track position at the assistant or associate professor level. The Department of Electrical Engineering is seeking an individual who will have an earned Ph.D. or equivalent by the contract start date to teach and perform research in signal processing (a) theory, (b) implementations in hardware and software and (c) applications in control or communication systems. The department currently offers degrees through the doctorate and has approximately 300 undergraduates and 150 graduate students. The University of Dayton is situated in a dynamic, high technology area where there is a wide range of cultural and professional activities. Salary and starting date are negotiable with the latest starting date being August 16, 1993. Send vita and the names of addresses of three references to: Dr. Don Moon, Chairman, EE Dept., University of Dayton, 300 College Park Drive, Dayton, OH 45469-0226. UD is an EEO/AA employer.

Werner Graupe Chair in Manufacturing Automation. The Faculty of Engineering of McGill University invites applications for this new endowed chair. The Faculty has world-class strength in Robotics, and is looking to complement that strength with expertise that lies "upstream" in terms of Manufacturing. Specifically, areas of interest include: design automation, modelling and simulation of manufacturing systems, concurrent engineering and manufacturing planning and control. The successful candidate will also be put forward for an NSERC Industrial Chair, so as to create a junior position in the area. The appointment will be as a tenured or tenure-track Full Professor, in either Electrical or Mechanical Engineering, with cross appointment also possible. The proposed date of appointment is 1 January 1994. A Ph.D. is required, with a superior research record. Industrial experience is desirable. McGill is committed to equity in employment. Although preference will be given to Canadians or landed immigrants in Canada, all applications are welcome. Interested candidates should send their CV to: Professor Pierre R. Belanger, Dean of Engineering, McGill University, 817 Sherbrooke Street West, Montreal, Quebec, Canada, H3A 2K6.

The University of Alabama seeks a tenure-track faculty member in the Department of Electrical Engineering at the assistant professor level. Departmental needs are in the areas of computers and control systems. Duties include both teaching and research activities, and the faculty member is expected to develop externally funded research programs involving graduate students. The University is located in Tuscaloosa, AL, which has a metropolitan area population of 150,000, is a one-hour drive from Birmingham and three hours from Huntsville, where many NASA and DOD research facilities are located. Applicants must have an earned doctorate in Electrical or Computer Engineering, or in a closely related field. U.S. citizenship or permanent resident status is required. Salary is commensurate with qualifications. Send a resume to Dr. Russell L. Pimmel, Head, Department of Electrical Engineering, The University of Alabama, P.O. Box 870286, Tuscaloosa, Alabama 35487-0286. The Search Committee will begin considering applications February 15, 1993 and will continue until the position is filled. Female and minority candidates are strongly encouraged to apply. The University of Alabama is an Equal Opportunity/Affirmative Action employer.

Union College - Dean of Engineering. Union College invites applications and nominations for the position of Dean of Engineering. Responsibilities: The Dean of Engineering reports to the Vice President for Academic Affairs and provides leadership to the Engineering Division. Responsibilities include curricular and budgetary development as well as faculty recruiting, development and evaluation. The new dean will be innovative in promoting an effective working relationship among faculty and administrators, and will be vigorous in promoting industrial and international experience for students and in integrating engineering with the liberal arts. The position includes teaching one course per year in one of the engineering departments. Qualifications: An earned doctorate in engineering or a closely related field. A distinguished record showing commitment to teaching and research. Demonstrated administrative ability, interpersonal skills and effective communication. A commitment to diversity in the recruitment of faculty and students. A commitment to excellence in general and technical education. The School: Located in the Capital District of New York State, Union is a private, selective four-year college about to celebrate its 200th anniversary. The college has a distinguished 150-year history of engineering in a liberal arts setting. The Division of Engineering and Applied Science, with 28 full-time faculty, has ABET-accredited undergraduate curricula in Civil, Electrical and Mechanical Engineering, and an undergraduate curriculum in Computer Science. Additionally, there are master's programs in Electrical Engineering, Mechanical Engineering and Computer Science. The college is currently engaged in a bicentennial capital campaign of $150 million of which $20 million has been earmarked for the endowment of science and engineering equipment. Applications received before February 15, 1993 will be given priority. Nominations and applications, including resume and the names, addresses and telephone numbers of three references, should be sent to: Dr. David Hannay, Chair, Dean of Engineering Search Committee, EE/CS Department, Steinmetz Hall, Union College, Schenectady, NY 12308-2311. Union College is firmly committed to Affirmative Action and strongly encourages women and minorities to apply.

Stanford University invites applications for a mid-career or senior-level tenured faculty appointment in Manufacturing. Candidates

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IEEE United States Activities has updated and reissued its "Directory of Volunteer Opportunities in Precollege Mathematics and Science Education for Engineers and Scientists." The new edition was printed jointly by IEEE-USA and the Engineers for Education program.

The directory lists 34 extracurricular programs that seek to improve and enhance math, science, and technology education for elementary and secondary school students. The programs are nationally coordinated but operate locally in various cities. All are heavily dependent upon volunteers for their human resources.

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Rice University, Department of Electrical and Computer Engineering invites applications for a senior faculty position in the area of Robotics. Applicants should be interested in space or undersea applications and be able to lead a robotics laboratory. Candidates should have a proven record of accomplishment, and be at the senior Associate Professor or recently appointed Full Professor level. Rice University is a small, private university with a strong commitment to excellence in both teaching and research. Rice is located in Houston, Texas, a city with affordable housing and excellent fine arts. Applicants should submit their resume, a summary of their research accomplishments, and the names of at least three references to the Chairman of the Department of Electrical and Computer Engineering, Rice University, P.O. Box 1892, Houston, TX 77251-1892. Rice University is an equal opportunity/affirmative action employer.

University of Central Florida (UCF): The Electrical and Computer Engineering (40 faculty, 950 undergraduates, 400 graduates) anticipates tenure-track openings at the assistant professor level in computer engineering (digital systems/architecture, software engineering, networks). All applicants must have a Ph.D. at the time of employment and a strong commitment to teaching and research. Applications must be post-marked by Feb. 10, 1993 and must be sent to: Dr. N.S. Tzannes, Chair, Electrical and Computer Engineering, University of Central Florida, Orlando, Florida 32816. UCF is an equal opportunity/affirmative action employer. As an agency of the State of Florida, all application materials and selection procedures are available for public review.

Mississippi State University invites applications for four tenure-track positions in the Department of Electrical and Computer Engineering. Applicants should have a strong background in one of the following areas: (1) analog IC design with experience with electronic systems and CAD tools, (2) electromagnetics with experience in computational field simulation, (3) high-performance digital systems design with experience in custom VLSI system hardware and software, and (4) electric power systems analysis or high voltage. The first three positions are in conjunction with the MSU/NSF Engineering Research Center for Computational Field Simulation which is one of the nation's 18 NSF centers. A Ph.D. and a strong interest in graduate and undergraduate teaching are required. Individuals will be expected to demonstrate ability to conduct sponsored research in one of the above four areas. Salary and position commensurate with qualifications. Applications will be accepted through March 1, 1993, or until positions are filled. Send resume and list of three references to Dr. G. M. Molen, Department of Electrical and Computer Engineering, P.O. Drawer EE, Mississippi State, MS 39762. MSU is an affirmative action, equal opportunity employer.

Southern Illinois University at Edwardsville, Department of Electrical Engineering - Applications are invited for a tenure-track faculty position. Top priority will be given to individuals with specific interests in electronics design and computer-aided design of integrated circuits. It is anticipated that the successful candidate will have a strong interest in applying computer-aided design in one or more application areas in which the department is interested e.g., computer architecture, artificial intelligence, image and signal processing and neural networks. The candidates should hold ■ Ph.D. degree in Electrical or Computer Engineering. Review of applications will begin February 15, 1993 and will continue until the position is filled. The department, consisting of ten faculty members, offers programs at the B.S. and M.S. levels. Last year, 58 bachelor's and 20 master's degrees were awarded. Southern Illinois University at Edwardsville is a state university in Illinois located in the St. Louis metropolitan area. Applicants should send curriculum vitae and three reference letters to: Professor Raghu Bollini, Chairman, Department of Electrical Engineering, Southern Illinois University at Edwardsville, IL 62026-1801. Southern Illinois University at Edwardsville is an Equal Opportunity/Affirmative Action Employer.

Wayne State University anticipates several openings for tenure-track faculty in the Electrical and Computer Engineering Department. We are seeking research oriented individuals in (i) computer engineering, with emphasis on any of the following; networks, parallel and distributed systems, high performance computing, analog/digital VLSI design, or artificial neural systems, (ii) photonic devices and systems with emphasis on any of the following; nonlinear optics, optical sensors, quantum interference, or multi-spectral processing, and (iii) controls, with emphasis on robust control. Applicants should have an earned Ph.D. and be committed to teaching and research. Rank and salary will depend on experience and qualifications. Wayne State is a large urban university, and welcomes applications from women and minorities. Resumes should be sent to Dr. M.P. Polis, Chair, ECE Dept., Wayne State University, Detroit, MI 48202. Wayne State University is an Equal Opportunity/Affirmative Action employer. Wayne State University - People working together to provide quality service.

Software MR Position-4 Tesla. Applicants are sought for a Software Engineer to b■ employed as ■ Research Associate or Research Fellow at the Center for Magnetic Resonance Research, Department of Radiology, University of Minnesota Medical School. The responsibilities of the position are 1) developing software for processing, analysis, and display of MR images and spectra, 2) developing and integrating application specific software modules into user friendly environment using X-windows, 3) specialized software development for control of data acquisition by magnetic resonance imaging instrument, 4) administration of the SUN workstations and the network and 5) debugging existing software problems. Applicants must have an MS degree in Computer Sciences or EE, or a PhD degree in physics with extensive computer programming training. Experience with SUN workstations, UNIX operating system, programming in C and X-windows is required. Image and signal processing experience is desirable. Previous experience with Magnetic Resonance instrumentation is preferred but not mandatory. Title will commensurate with degree. Start date is March16, 1993, with applications being accepted through March 1. A resume and three letters of recommendation should be sent to Professor Xiaoping Hu, Radiology Department, 420 Delaware Street S.E., University of Minnesota, Minneapolis, Minnesota 55455. Salary is negotiable and will be commensurate with experience. The University of Minnesota is an equal opportunity educator and employer.

Hardware MR Position-4 Tesla. Applicants are sought for a Research Associate or Research Fellow position at the Center for Magnetic Resonance Research, Department of Radiology, University of Minnesota Medical School. The position involves A) undertaking development of new digital and analog radio frequency electronics for a 4 Tesla "human" imaging/spectroscopy instrument to improve performance and research capabilities for MR imaging and in vivo MR spectroscopy studies on humans, and B) diagnosis of problems and their repair for the 4 Tesla instrument. The development related duties will include development of MR RF coils, low noise preamps, phased array front ends, gradient coil design and construction. Minimum requirements for the position are 1) PhD in physics, EE or related field with at least one year of experience, or MS in EE with three years of experience with digital and analog RF electronics, and 2) experience in programming digital hardware. Experience with Nuclear Magnetic resonance instrumentation is preferred. Titlle will commensurate with degree. Salary is negotiable.Start date is March 15, 1993, with applications being accepted through March 1. Please submit resume and three letters of recommendation to Professor Kamil Ugurbil, CMRR, 385 East River Road, University of Minnesota, Minneapolis, Minnesota 55455. The University of Minnesota is an equal opportunity educator and employer.

University of Arizona. The University of Arizona Electrical and Computer Engineering Department invites applications for one or more possible tenure track faculty appointments for the 1993-94 academic year. 1993-94 academic year appointments are dependent on budgetary decisions to be made in the 1993 Spring Semester. Preference will be given to applicants at the Assistant Professor level, but exceptional candidates at higher levels may also be considered. In addition to an earned doctorate and a commitment to excellence in teaching at both the undergraduate and graduate levels, it is essential that candidates have outstanding research achievement and/or potential and the commitment and ability to establish an externally sponsored research program. Technical areas of particular interest for 1993-94 recruiting are: (1) microelectronics emphasizing microelectronics manufacturing and/or semiconductor processing science; (2) network communications including interconnection networks for parallel processing systems. Applicants should send a resume, a statement of teaching and research interests, and a list of three references to: Prof. K.F. Galloway, Department Head, Electrical and Computer Engineering Department, University of Arizona, Tucson, AZ 85721. Applications will be reviewed starting January 15, 1993 and will be received until open positions are filled. The University of Arizona is an Equal Opportunity/Affirmative Action Employer and specifically invites women and minorities to apply.

University of Colorado at Denver, Department of Computer Science and Engineering Announces Faculty Position. The Department of Computer Science and Engineering invites applications for ■ tenure-track faculty position, beginning August 1993. We are interested in applicants with expertise in computer architecture, numerical analysis, simulation, distributed systems, programming languages, and cognitive science. We are particularly eager to receive applications from members of ethnic groups which are underrepresented in computer science. Candidates must have, or expect to receive no later than August 1993, an earned doctorate in computer science or a related field. Strong research potential and teaching ability at both the undergraduate and graduate levels are required for this position. An established research record is expected at appointment levels above initial assistant professor. Rank and salary will be commensurate with experience. CU-Denver is part of the four-campus University of Colorado system, and is situated in the heart of downtown Denver. The Denver area and the Rocky Mountain region offer numerous cultural and recreational opportunities. Send vitae and names and telephone numbers of at least three professional references by 19 February 1993 to: Professor John Clark, Chair, Faculty Search Committee, University of Colorado at Denver, Department of Computer Science and Engineering, Campus Box 109, P.O. Box 173364, Denver, CO 80217-3364. Phone: 303/556-4314, Fax: 303/556-8369, Internet: jclark@cudnvr.denver.colorado.edu. The University of Colorado at Denver is strongly committed to the diversity of its faculty and staff, invites applications from a broad spectrum of people, and particularly encourages applications from women, members of racial and ethnic minority groups, veterans, and persons with disabilities. Alternative formats of this solicitation are available upon request.

McGill University. The Department of Electrical Engineering of McGill University has a tenure-

CLASSIFIED EMPLOYMENT OPPORTUNITIES

track opening at the assistant professor level in the area of Photonic Systems and a second one in Computer Engineering. These vacancies are immediate and we desire to fill them by September '93. Applicants for the Photonics position must exhibit outstanding research accomplishments in free-space photonic systems. The successful individual will be expected to work closely in developing a strong research and teaching program with a recently appointed BNR/NT-NSERC Industrial Research Chairholder in Photonic Systems. The candidate for the position in Computer Engineering must have an outstanding research record and proven experience on large software projects such as those related to real-time, distributed, asynchronous event-driven systems. Candidates must have an earned Ph.D. degree and a genuine interest in teaching. A good first degree in Electrical Engineering is preferred, however, one in a cognate discipline coupled with appropriate professional experience would also be acceptable. Please send a resume and a list of three references to Professor Nicholas C. Rumin, Chairman, Department of Electrical Engineering, McGill University, 3480 University St., Montreal, Quebec, Canada, H3A 2A7. McGill University is committed to equity in employment.

Tenure Track Assistant Professor Position. The University of Missouri-Rolla seeks applicants for a 1993 tenure track assistant professor (PhD required) position. Only applicants with strong backgrounds in structural controls will be considered. Permanent residency or U.S. citizenship is essential at the time of employment. Please send resume and the names of three references to: W.J. Gajda, Jr., Chairman, Department of Electrical Engineering, University of Missouri-Rolla, Rolla, MO 65401. Application deadline is March 31, 1993. The University of Missouri is an Equal Opportunity/Affirmative Action employer.

Dean - Oakland University: Nominations and applications are invited for the position of Dean of Engineering and Computer Science. Founded in 1957, Oakland University is a comprehensive public institution with an enrollment of 12,500 students. Located in suburban Oakland County on 1500 park-like acres, the campus is adjacent to the Oakland Technology Park. Oakland University is a major educational and cultural center. Oakland County is the most rapidly expanding county in Michigan and is home to over 400 multi-national corporations. The School of Engineering and Computer Science enrolls 1230 students including 860 undergraduate and 370 graduate students. ABET accredited undergraduate programs are offered in Computer, Electrical, Mechanical and Systems Engineering, plus a CSAB accredited undergraduate program in Computer Science. There are M.Sc. programs in ECE, SE, ME and CSE and an interdisciplinary Ph.D. program in Systems Engineering. Undergraduate degrees in Engineering Chemistry and Engineering Physics are offered as joint programs with the College of Arts and Sciences. The Dean provides academic leadership to the 34 full-time faculty; supports teaching and research; and engages in the planning, budgetary, personnel review, fund raising and public service activities needed to ensure the growth of the School. The Dean reports directly to the Vice President for Academic Affairs. Candidates should hold an earned doctorate in engineering or an applied science; have a history of research activity with success in gaining external support; and have a strong administrative background. Applicants must have a demonstrated commitment to integrity, the promotion of excellence and achieving cultural diversity. The successful candidate must have achieved the distinction appropriate for a tenured faculty position at the full professor level in the School. To ensure full consideration, applications must be received by February 22, 1993. Applications should include a current resume plus the names, addresses, and phone numbers of at least three references. Send nominations and applications to: Dean Search Committee, Professor Glenn A. Jackson, Chair, Office of the Vice President for Academic Affairs, Oakland University, Rochester, MI 48309-4401. Oakland University is an affirmative action/equal opportunity employer and encourages applications from women and minorities.

Postdoctoral Research Position: Applications are invited for a postdoctoral research position in developing new algorithms and new concepts for image reconstruction from cone-beam projections. Requirements include elementary knowledge of tomography and of signal processing; and experience with FORTRAN, C and UNIX. Applicants should send a resume and arrange three letters of recommendation to be sent to: Bruce D. Smith, Mathematical Sciences Department, Mail Location 25, University of Cincinnati, Cincinnati, OH, 45221. For more information send E-mail to smithbu@ucunix.uc.edu. An equal opportunity/affirmative action employer.

Computer Engineering: The University of Bridgeport Department of Computer Science and Engineering invites applications for two tenure track positions at all ranks. A Ph.D. in computer or electrical engineering and a strong interest in undergraduate and graduate teaching is required. Areas of specialization should include at least one of the following: computer communication, parallel processing, real-time systems, VLSI design, and computer architecture. A demonstrated ability in, or potential for, independent research is important. The Department has two workstation labs composed of HP/Apollo and Sun workstations using Mentor Graphics and Altera software, among others. A Solbourne 700 serves the Suns and PCs over an ethernet backbone. Interested applicants should send their resumes and the names and addresses of at least three references to: Prof. Stephen Grodzinsky, Chair, Computer Science and Engineering, University of Bridgeport, Bridgeport, CT 06601 or grodzins@cse.bridgeport.edu. Applications will be reviewed on a rolling basis until the positions are filled. Equal Opportunity Employer.

Manufacturing Research Faculty Positions. Tennessee Technological University is seeking applicants for senior-level faculty positions in the Center for Manufacturing Research and Technology Utilization. Applicants must have a distinguished record of teaching, scholarship, and manufacturing-related research in Computer-Aided Design & Manufacturing of Plastic Components, Image Processing, Manufacturing Systems, Real Time Robot Control, Sensor Fusion, Vibration Testing and Analysis, and/or Mechanical Properties of Materials. An earned doctorate in an appropriate engineering discipline, a documented record of extramurally funded research, and strong interpersonal skills are also required. A demonstrated ability to interface with manufacturing industries and involvement in professional organizations are also highly desirable. These are nine-month, tenure-track positions with a major responsibility for obtaining and conducting externally-funded research projects. The maximum teaching load is one course per semester. Rank and salary will be commensurate with experience and qualifications. The positions are available August 1, 1993. A complete resume and the names, addresses and telephone numbers of four references should be submitted to Dr. Joe Scardina, Chairman of Search Committee, Center for Manufacturing Research, Box 5077, TTU, Cookeville, TN 38505, (615) 372-3362. Review of applications will begin in February 1993, but the positions will remain open until filled. Affirmative Action/Equal Opportunity Employer.

University of Florida. Student Eminent Scholarship positions are available for highly qualified students in Electrical Engineering starting Fall 1993. Recipients are expected to earn a Ph.D. degree in 4 years (beyond the B.S. degree) and to have a strong interest in research. During at least one semester, supervised class room teaching will be part of the recipient's program. Applicants must possess a BSEE degree and have truly outstanding academic credentials such as: a rank in the top of their class and a near perfect GPA. In addition, a GRE score of at least 1350 (Verbal plus Quantitative) is preferred. The stipend is $15,000 per calendar year plus a tuition waiver and will be awarded for 4 years upon satisfactory progress. Application forms, with a return deadline of March 15, 1993, can be obtained from: Dr. Gijs Bosman, Department of Electrical Engineering, University of Florida, Gainesville, FL 32611.

Auburn University. The E.E. Department at Auburn University currently has openings for faculty with expertise in any of the following specific areas: computer and parallel architecture, parallel processing, VLSI systems, computer aided design, digital/microprocessor control, precision control and sensors, and robotics. In the controls area, hardware experience is preferred. Applicants must be research oriented, have a Ph.D., and an electrical engineering background. Senior level appointments are available. Applicants must be able to provide documentation of the right to work in the U.S. Auburn is Alabama's land-grant university with 22,000 students. The E.E. Department has 27 faculty and currently enrolls approximately 500 undergraduate and 100 graduate students. The annual research funding level is approximately $2 million. Interested persons may send resumes to Professor L.L. Grigsby, Chairman of Faculty Search Committee, Department of Electrical Engineering, Auburn University, AL 36849-5201. The deadline for receipt of applications is March 1, 1993. Minorities and women are encouraged to apply. Auburn University is an equal opportunity and affirmative action employer.

The University of Alabama in Huntsville, Department of Electrical and Computer Engineering, seeks U.S. citizens or permanent residents holding the Ph.D. in electrical or computer engineering, or in cognate fields, to fill two positions in controls, high-speed communications, or VLSI design. Junior appointees should have outstanding potential as teachers and researchers; senior appointees should possess a record of substantial research support and productivity as well as teaching ability. The department, with 26 faculty members, currently enrolls more than 630 students in baccalaureate programs in electrical engineering, computer engineering, and optical engineering, and more than 250 graduate students in masters and doctoral programs in electrical and computer engineering, and participates in the Ph.D. program in optical science and engineering. Huntsville, a culturally diverse, high technology community of twenty thousand scientists and engineers, provides a major federal and corporate base for collaboration, support and consulting. Situated on the Tennessee River, in the Appalachian foothills, its climate is temperate; opportunities for recreation and cultural activities abound. Salary and benefits are competitive, while housing is very affordable. Please send curriculum vitae with the names of three references to Professor Stephen T. Kowel, Chairman, Department of Electrical and Computer Engineering, The University of Alabama in Huntsville, Huntsville, Alabama 35899. UAH is an Affirmative Action/Equal Opportunity Institution.

Boston University. The Department of Electrical, Computer and Systems Engineering at Boston University seeks applications for three anticipated faculty positions in the areas of data communications, computer systems and signals and systems. All positions are for tenure track or tenured appointments starting in September 1993. An earned PhD in a relevant discipline is required. Faculty are expected to develop a program of funded research in their area of expertise. Boston University is located in the heart of the Boston academic community along the Charles River, with easy access to the outstanding scientific, cultural and tourist attractions of the city. The Department has 31 faculty and approximately 50 PhD, 250 MSc and 600 BSc majors. Opportunities exist for collaboration with other colleagues in the Boston area, as well as with the leading electronics and software companies in the area. Applicants should send their curriculum vita to Professor Thomas G. Kincaid, Chairman, Department of Electrical, Computer and Systems Engineering, Boston University College of Engineering, 44 Cummington Street, Boston, MA 02215. Boston University is an Equal Opportunity/Affirmative Action Employer.

Chairperson, Electrical Engineering, University of New Orleans. The University of New Orleans invites nominations and applications for

the position of Chairman of the Electrical Engineering Department. Candidates must hold an earned doctorate in electrical engineering (preferably in communications and signal processing, control systems, or computer engineering), have an excellent record of sponsored research and publications, and be eligible for appointment to the rank of full professor. Prior administrative or industrial experience and involvement in professional societies are desirable. The chairman is expected to provide leadership in the development of research and in the maintenance of the quality of our undergraduate and graduate programs. Application review will begin on February 1, 1993 and continue until the position is filled. Applicants should send a letter of interest with resume and names, addresses and telephone numbers of at least four references to Dr. John N. Crisp, Dean, College of Engineering, University of New Orleans, Lakefront, New Orleans, Louisiana 70148. The University of New Orleans is an equal opportunity/affirmative action employer.

The University of Rhode Island, Department of Ocean Engineering Faculty Position. The Department of Ocean Engineering, College of Engineering, University of Rhode Island invites applicants for a tenure-track position at the Assistant or Associate Professor level, starting in the 1993 Fall semester. The Department, founded in 1966, has undergraduate and graduate (B.S., M.S., Ph.D.) programs with areas of concentration in ocean instrumentation, data analysis, underwater and subbottom acoustics, marine structures, hydrodynamics, marine geomechanics, numerical modeling of nearshore processes, coastal engineering, and marine materials. The Department shares facilities with, and has excellent working relationships with, the Graduate School of Oceanography. The University of Rhode Island is situated near Narragansett Bay with access to an extensive variety of marine research facilities. Ph.D. in engineering or science required. Demonstrated record of research, scholarly productivity, and teaching experience preferred. Preference will be given to candidates with specialization in ocean data analysis and instrumentation. Candidates for appointment at the associate professor level must have a strong record of research, scholarly productivity and teaching experience. This is a tenure track position starting in the 1993 Fall semester. Applications will be accepted until December 31, 1992, or until the position is filled. Send resume, names of three references and evidence of ability or potential to generate funded research to: Malcolm Spaulding, Search Committee Chair, (Log #081030), University of Rhode Island, P.O. Box G, Kingston, RI 02881. An Affirmative Action/Equal Opportunity Employer.

Electrical Engineering: Tenure track faculty position available at the Assistant, Associate, or Full Professor level in the Electrical Engineering Department, South Dakota School of Mines and Technology. Primary need is for applicants with specialization in the areas of Computer Engineering or Electrical Engineering, with emphasis in computers and digital systems. Responsibilities will include both teaching and research. Applicants must possess a doctoral degree in Electrical or Computer Engineering, or be scheduled to complete all degree requirements by September 1, 1993. Salary is commensurate with qualifications and experience. South Dakota School of Mines and Technology, founded in 1885, has an enrollment of approximately 2,500 students and offers degrees in all the major branches of engineering and the physical sciences. Applications, including a resume, a statement of teaching and research interest, and names and addresses of at least three references should be sent to: Dr. A.L. Riemenschneider, Department Head, Electrical Engineering Department, South Dakota School of Mines and Technology, 501 East St. Joseph Street, Rapid City, SD 57701-3995. Phone (605) 394-2451. Applications are desired before March 1, 1993, but the search will remain open until the position is filled. South Dakota School of Mines and Technology is an equal opportunity, affirmative action employer, and encourages applications from qualified women and minorities.

University of Idaho Department of Electrical Engineering invites applications for tenure-track positions at the assistant, associate and professor levels in the areas of instrumentation and control systems. Specialty sub-areas include analog electronics, power electronics, digital signal processing, control systems, or sensing devices. If suitable candidates in these specialties are not identified, candidates in electromagnetics, computer engineering or digital systems may be considered. Duties include teaching at the graduate and undergraduate levels, research in the specialty area, and contributing to the academic program in the Department. Qualifications include an earned PhD in electrical engineering or closely related field, excellent teaching ability, potential for a strong research program and US citizenship or permanent residency. Industrial experience in the specialty area is desirable. The Department offers the BS, MS and PhD in electrical engineering and the BS and MS in computer engineering. Research activity includes the Microelectronics Research Center, the National Center for Advanced Transportation Technology and projects jointly with regional industry. The University of Idaho has statewide responsibility for engineering education, and the Electrical Engineering extension program in Boise, the state capital, is near major engineering companies. There are approximately 50 students in the growing Electrical Engineering program in Boise, which is primarily an evening program. Search and selection procedures will be closed when a sufficient number of qualified applicants has been identified, but not earlier than February 1, 1993. Send letter, resume, and names of three references to Dr. James Peterson, Department of Electrical Engineering, University of Idaho Boise Engineering, 1910 University Drive, Boise, ID 83725. The University of Idaho is an EO/AA employer. Positions are contingent on funding.

The Center for High Technology Materials (CHTM) at the University of New Mexico invites applications for a tenured/tenure track faculty position in Optoelectronics. The successful applicant will work with other optoelectronics faculty in the design, growth, fabrication and evaluation of novel optoelectronic materials, devices and integration, and will also be expected to establish an independent research program. On-going research at CHTM includes vertical-cavity surface-emitting lasers, optical switches, high-power laser diodes and arrays, visible laser diodes, nonlinear optics and fiber lasers and amplifiers. Another major thrust area is manufacturing metrology and process control for both optoelectronics and microelectronics. Existing facilities include two MOCVD systems, a well-equipped Class-100 processing facility and extensive optical and electronic characterization. Faculty appointments are in an academic department associated with CHTM. A Ph.D. in Physics, Electrical Engineering, Material Science or a related field is required. Rank and salary will be commensurate with qualifications and experience. Send resume and list of three (3) references to: Dr. Julian Cheng, Chair, Search Committee, CHTM, EECE, Room 125, University of New Mexico, Albuquerque, NM 87131 before March 1, 1993. The University of New Mexico is an Equal Opportunity/Affirmative Action Employer.

The University of Nevada, Las Vegas, Department of Electrical and Computer Engineering invites applications for tenured and tenure track positions. Applications are accepted in the areas including but not limited to Computer Engineering, Power Engineering, Communications, and Electromagnetics. Preference will be given to senior level applicants with outstanding research and teaching records. Senior level applicants will be expected to provide leadership in the anticipated Ph.D. program. Applicants must have earned a doctorate in electrical or computer engineering. Send resume and names of 3 references to: Chairman, Search Committee, University of Nevada, Las Vegas, Department of Electrical and Computer Engineering, CSE-4026, 4505 Maryland Parkway, Las Vegas, NV 89154-4026. Applications will be considered as they are received, and will be accepted until the positions are filled. The University of Nevada, Las Vegas, is an equal opportunity/affirmative action employer. UNLV employs only U.S. citizens and aliens authorized to work in the U.S.

Research Engineer. The NSERC/MPR Teltech Research Chair in RF Engineering, of the Department of Electrical and Computer Engineering, at the University of Victoria, is seeking a research engineer to participate in advanced research in numerical time domain modeling of electromagnetic fields, with applications in computer-aided design of microwave and millimeter-wave circuits, antennas, high speed digital circuits, and EMI/EMC. This position requires extensive knowledge and experience in electromagnetic field theory, numerical modeling, and in electromagnetic/microwave engineering. The candidate must meet all of the following minimum requirements: A Ph.D. degree in Electrical Engineering with specialization in electromagnetic and microwave modeling. Experience/knowledge in the following areas: Microwave CAD, Microwave Measurements (Scalar and Vector Network Analyzer, Spectrum Analyzer), and EM instrumentation. Industrial experience in the design and development of RF, microwave and millimeter-wave systems and sub-systems. Advanced working knowledge of both Frequency and Time Domain Numerical Methods such as Finite Element, FD-TD and TLM methods. Working experience with supercomputers such as DEC mpp 12000 or the Connection Machine. Knowledge of Fortran 90. A solid publication record in leading International Journals and Conferences. We offer industry-competitive salaries and a complete fringe-benefit package. For consideration, forward your resume and salary requirements before March 1, 1993 to Professor W.J.R. Hoefer, NSERC/MPR Teltech Research Chair, Department of Electrical & Computer Engineering, University of Victoria, P.O. Box 3055, Victoria, B.C., V8W 3P6, Canada. The University of Victoria is an employment equity employer and encourages applications from women, persons with disabilities, visible minorities and aboriginal persons.

The University of Southern California. The Electrical Engineering-Systems Department invites applications for several tenure track positions. Preference will be given to senior-level applicants who have demonstrated a leadership ability in building a strong research program, and who also have a distinguished teaching and research record. Areas of interest include: communication networks for multimedia applications with an emphasis on the lower layers of the OSI network model (physical, link protocol and routing/signaling aspects); statistical communication and/or signal processing algorithms and their VLSI implementation; computer aided design for digital systems; multidimensional signal processing oriented toward image processing with an emphasis on compression, real-time acquisition, 3-D adaptive processing, fusion and understanding; array signal processing. We also invite applications for tenure-track Assistant Professors in the area of intelligent control with emphasis on intelligent vehicles and highways. Applications must include a comprehensive resume, a list of three to five professional references, and a letter of interest indicating clearly the position designated above for which you are applying. Please send material to Chairman, EE-Systems Search Committee, EE-Systems Department, USC, Los Angeles, CA 90089-2560. USC is an Affirmative Action/Equal Opportunity Employer and encourages and welcomes applications from women and minorities.

Assistant Professor - Computer Engineering. The Department of Electrical Engineering, The University of British Columbia, invites applications for a tenure-track Assistant Professor appointment in Computer Engineering. The broad area of software engineering, including real-time or distributed applications, is of primary interest. Outstanding applicants in computer-aided design of digital systems or microelectronic circuits, or in other areas which support computer engineering also will be considered and are encouraged to apply. A Ph.D. is required. Industrial and/or teaching experience is desirable. The successful applicant will be expected to pursue research vigorously, and to teach effectively at the graduate and undergraduate levels. Departmental facilities are extensive and include approximately 200 networked workstations and microcomputers, a shared array of parallel processors, image processors, integrated circuit and system design tools, and fabrication facilities. Collaboration with the Department of Computer Science is encouraged and facilitated through the Centre for Integrated

Computer Systems Research. Industrial collaboration and support is available. Salary is commensurate with qualifications and experience. Start-up funding is available for purchase of equipment and support of graduate student research assistants. The position is available from July 1, 1993. Priority will be given to applications received on or before April 30, 1993. To apply, send a curriculum vitae, reprints of published papers, names of at least three references, and a statement of eligibility for employment in Canada to: Dr. R.W. Donaldson, Head, Department of Electrical Engineering, The University of British Columbia, 2356 Main Mall, Vancouver, B.C. Canada V6T 1Z4. The University of British Columbia welcomes all qualified applicants, especially women, aboriginal people, visible minorities, and persons with disabilities. In accordance with Canadian Immigration requirements, priority will be given to Canadian citizens and permanent residents of Canada.

Brigham Young University, Computer Science Department, Assistant Professor - Applications are invited for an Assistant Professor position beginning September, 1993. Applicant must have a PhD and should have strong research orientation and scholarly ability. Current areas of research in our PhD and MS programs include User Interfaces, Neural Networks, MultiMedia, Communications/Networking, Software Engineering, Robotics, and Computer Vision. The Computer Science Department is housed in a new 54,000 square foot facility with well equipped teaching and research laboratories. Applicants should send a curriculum vita to E. Daniel Johnson, 3362 TMCB, Brigham Young University, Provo, Utah 84602. BYU is an EEO/AA employer and is sponsored by the Church of Jesus Christ of Latter Day Saints. Preference is given to LDS applicants.

Government/Industry Positions Open

Electrical Engineer: To be responsible for all plant electrical, with specific responsibilities for melt shop arc furnace regulation, plant power distribution, static var compensators, electrical specifications for all electrical equipment, and electrical supervision of the electrical team of technicians. 5 years experience in power distribution & steel mill melt shop arc furnace regulation, plus B.E. in electrical engineering required. 40 hrs/wk. Hrs. 7–3:30. $952.00 week salary. One position available in Blytheville, Arkansas area. To apply: Mail resume with copy of ad attached to Employment Security Division, PO Box 1409, Blytheville, Arkansas 72315, J.O. #663594.

Software Engineer: 40 hr. workweek, overtime open 9. a.m.–5 p.m. Basic $20 per hr., O.T. $30 per hr. Job requires a minimum of ■ Masters Degree in Electrical Engineering or Computer Science. In addition, there should be a minimum of 8 graduate level credit hours in software design and computer languages plus 8 graduate credits in Micro-Processor Architecture. At least 1 year experience in software engineering. Job involves the design of automotive electrical control units to conform to the specifications and requirements of future car line engine and transmission controllers. Write and document engine and transmission controller software in a real time environment. Send resumes to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Reference #71292. Employer paid ad.

Electrical Engineer—40 hr./wk. O.T. as required. Work scheduled 9 to 5. Pay $28/hr. O.T. $42/hr. Requires M.S. Degree in Electrical Engineering. Minimum of 12 graduate level credits in applied mathematics, which must include Numerical Analysis and Matrix Theory. Additional 12 graduate level credits in Semi-Conductor Device Physics, covering energy band and transport phenomenon and operating properties such as DC, AC, Transient and Noise models of FETs, BJTs and LEDs. The job involves the modeling of automotive electrical/electronic circuitry for purposes of predicting design performance using SABER or SYSCAP. Device physics models are to be created for use in Failure Mode Effects Analysis, Worst Cast Analysis, Sensitivity Analysis and Statistical Studies. Written technical reports are prepared for each study. Send resumes to 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Reference #78092. Employer paid ad.

Engineer: Senior Software. Develop, maintain & support the in-house analog simulator. Knowledge of electronic circuit design, circuit theory, signal processing, algorithm development, system design, numerical analysis. Knowledge of & able to use analog simulator including Spice. Knowledge of Stability theory & convergence analysis. Knowledge of graphics post processing s/w & digital signal processing support. Knowledge of Nonlinear system analysis & Stochastic Processes. Able to program in Fortran & C languages under Unix & CMS o/s. Jobsite: Santa Clara, CA Ph.D. in EE or CS. Entry Lvl. Salary: $4585/mo. 40 hrs./wk. Clip ad & submit w/resume to IEEE Spectrum, Box 1-1, 345 E. 47th St., New York, NY 10017 before Jan. 15, 1993.

Loss Control Engineer: 5 yrs min Electrical Utility safety/loss control plus Ins Co experience required. CSP/EE or equiv; ARM a plus. Proficiency in NESC, OSHA, EPA & other Fed Regs affecting EUs. Expr in EU acc/invest, injury mgt, clms eval, post-clm protocols & corrective LC programs. Ability to work with small municipal EUs & REAs. Familiar with qnt analysis, mgt systems & incentive prog. Water, wastewater & gas LC expr desirable. Position req devel & implement appd LC prog, train'g curric & performance audits. Field & auditorium presentation trg'g skill necessary. Engr must be self-motivated & able to perform with min supervision. Able to communicate with execut's and field crews. Reloc to Tenn Valley; 75% travel in SE with Co car & expenses. Send resume with details of expr & qualif's and salary requirement to: Gene L. Jones, Pres. Claims Management Services, Inc. PO Box 1447, Roswell, GA 30077-1447.

Electrical Engineer for N.W. Ohio consulting engineering firm. Duties include: Hardware and software design of distributed control systems. Plant automation and supervisory control and data acquisition systems. (SCADA) programmable logic controller systems layout. (PLC) design and implementation of dedicated microcontrollers. System integration. System modeling and identification of process dynamics. Computer programming in assembly language, Fortran and "C". Programming of Square D, Allen Bradley and Westinghouse controllers. Independently handle projects from design to completion. Interface with clients. Impart training to client users. Observe construction and make recommendations. Design program operator interfaces. Four to five trips per month for two days each at various job sites. Job requires MS degree in electrical engineering with major field of study in controls and communication and one year experience as an electrical engineer which experience may be gained before, during or after completion of M.S. degree and may b■ gained either in the field or as an instructor. Job further requires knowledge of analog and digital control system analysis and design system identification, and mathematical modeling as demonstrated by master's thesis or publication of one paper, or five graduate level courses encompassing these subjects. 40 hrs/wk 8 a.m. - 5 p.m. Monday thru Friday $17.74 per hour. Must have proof of legal authority to work indefinitely in the U.S. Send resumes in duplicate (no calls) to J. Davies, JO #1333963, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Senior Network Coordinator. 40 hours per week; 8:30a.m. to 5p.m., $18.27 per hour. Design hardware and support Ethernet TCP-IP networks, departmental and institutional. Provide project management for network installations, including status updates and complete documentation. Support the campus backbone networks and related network services. Insure that new equipment is installed, tested, documented and performance tracked. Assist in resolving software, hardware and vendor conflicts. Provide solutions to problems directed to the Data Communications area. Must have a Bachelor of Science degree in Electrical Engineering. Must have 1 year experience in the job offered or 2 years experience as an Installation Analyst. A Master of Science in Computer Science can substitute for the 1 year experience in the job offered or the 2 years experience as an Installation Analyst. Must have either one Master's level course in LAN or 1 year experience working with LAN. Must have proof of legal authority to work permanently in the U.S. Send resume to: Illinois Department of Employment Security, 401 S. State St., 3 South, Chicago, IL 60605, Attention: Len Boksa. Reference # V-IL 6209-B. No calls. An employer paid ad.

Electrical Engineer. Bellevue, WA consulting engineering firm seeks senior electrical engineer to provide electrical and instrumentation design, construction assistance, and commissioning for refineries and other high tech facilities. Must have BSEE plus five years experience as an Electrical Engineer, including four years in consulting companies. Prior experience must include design of power distribution, motor control, including programming of PLC's, process control and instrumentation, DCS configuration for refineries and other high tech facilities. Knowledge of AutoCAD and personal computers required. Must have proof of legal authority to work in the United States. Salaried position. $24 per hour. 40 hour week. 8:00 a.m. to 5:00 p.m. Benefits package includes bonuses and stock options. Send resume by February 4th to: Employment Security Dept., E&T Division, Job No. 348436-G, P.O. Box 9046, Olympia, WA 98507-9046.

Senior Resident Electrical Engineer: Design, develop, modify and implement process control systems for new and existing equipment and facilities for expansive manufacturing environment for various control systems designs and applications, including those using variable speed motor drives, distributed digital drive systems and programmable logic controllers; direct troubleshooting for all existing control systems; manage control systems interaction with other systems and installations including electrical power distribution systems, lighting, alarms, communications and paging. Minimum Requirements: Must have Master of Science in Electrical/Controls Engineering and at least 3 years industrial experience as control systems engineer, which must have included industrial experience in design, modification and implementation of process control systems for equipment and facilities in manufacturing environment, and related power distribution. This experience must also have included at least 2 years experience (which may have been concurrent) in the application of each of the following: (a) variable speed Alternating Current and Derivative Current motor drives; (b) distributed digital drive systems; (c) programmable logic controllers; (d) design of Proportional Integrative and Derivative control loops; and (e) project management experience in control systems design and implementation, with at least one project completed with value of $500,000 or more. Terms: $49,200 per year. Send resume to S. Springmeyer #2-124, Minnesota Department of Jobs & Training, Room 203, 777 E. Lake Street, Minneapolis, MN 55407. EOE.

Power Distribution/Gen & instrumentation exceptional opptys nationwide/int'l $46-86K. Confidential resume to Gresham & Gresham, employment consultants, P.O. Box 820888, Houston, TX 77282. Will call home. Est. 1966 Mem. AIChE, ISA, SPE (713) 780-1000 Fax 781-3300.

Electrical Design Engineer, Projects, for manufacturer in N.E. Ohio. Job Duties: Designs and directs activities of engineering personnel engaged in the design of electrical control systems and apparatus used to control proprietary, custom designed equipment including, but not limited to, air knife coaters, rod coaters, blade coaters, and web handling equipment. Writing operation and maintenance manuals for customers, preparing proposals and making presentations to customers, engineering personnel,

in English or Spanish language. Job requirements: BS Electrical Engineering, min. 3 yrs exp. paper mill engineer, must have at least two years experience with paper mill coating machinery including coaters, electrical drives, and control systems. Must be fluent in written and spoken Spanish. 40 hrs/wk, 8am-5pm, 1-10 hrs/wk O.T. $45,000.00 per year. Responders to this ad must have proof of legal authority to work indefinitely in the U.S. Send resume in duplicate (no calls) to: L. Ellison, JO#1350942, Ohio Bureau of Employment Services, PO Box 1618, Columbus, Ohio 43216.

Engineers, SS7/Cellular, U.S. Intelco Networks, Inc. develops innovative information services in the telephony industry. We need two experienced engineers to design, test and document new services for SS7, Cellular, AIN and PCS. Candidates must have 5+ years of telecommunications experience; preference for SS7 or cellular service background. We offer competitive compensation and a comprehensive benefits package. Fax your resume to (206) 493-6233 or mail to: Engineer Search, U.S. Intelco Networks, Inc., P.O. Box 2909, Olympia, WA 98507. EOE.

Sr. Electrical Engineer/Department Head. Central N.H. consulting engineering firm invites applications for a senior electrical engineering position. Position includes Department Head opportunity for qualified candidate. Applicants must be licensed engineers with a minimum of 10 years experience in engineering firms designing power transmission, distribution, control and instrumentation systems for industrial and institutional clients. Resumes should be sent to E.D. Clark, Rist-Frost-Shumway Engineering, P.C., 71 Water Street, Laconia, N.H. 03246.

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IEEE heads up National Engineers Week

Some 60 organizations will follow the lead of the IEEE-United States Activities unit in sponsoring this year's National Engineers Week, Feb. 14–20. Leadership rotates among 13 of the participating societies.

Chair of the event is IEEE President Martha Sloan; honorary chair is Kenneth T. Derr, chairman and chief executive officer of Chevron Corp., San Francisco. Theme of the event is "Turning Ideas Into Reality." Some highlights include:

• During the week, about 30 000 engineers in the Discover "E" (for energy) campaign will be visiting schools to urge over three million students and teachers to discover engineering and technology and to consider how mathematics, science, and engineering apply to the practical world.

• Students will visit engineering facilities and work side by side with practicing engineers. Engineers will also sponsor science fairs that include hands-on exhibits, demonstrations, career guidance meetings, and competitions.

• Winners of the Future City Competition for seventh- and eighth-graders will be announced on Feb. 17 at the Department of Energy in Washington, D.C.

• Also on Feb. 17, winners in the "Visions of Technology: Powers of Energy" photo contest will be announced.

Information on National Engineers Week is available from IEEE Public Relations, 1828 L St., N.W., Suite 1202, Washington, D.C. 20036-5104; 202-785-0017; fax, 202-785-0835.

Presidents-Elect nominated

At its meeting last month, the IEEE Board of Directors nominated two candidates for 1994 President-Elect. They are Luis T. Gandia of Santurce, P.R., the 1992–93 Vice President–Regional Activities, and James T. Cain of Pittsburgh, the 1991–92 Vice President–Publication Activities.

1993 honors ceremonies

The 1993 IEEE Medals, Corporate Recognitions, Service Awards, and Honorary Membership will be presented and new IEEE Fellows will be honored at the Sheraton Hotel and Towers in Chicago on Feb. 27. The occasion will also mark the 100th anniversary of the IEEE Chicago Section.

Ask*IEEE document delivery starts

The IEEE has entered the document delivery business with a service enabling researchers to obtain scientific and technical articles by phone, fax, electronic mail, or on-line. Ask*IEEE supplies articles from the Institute's journals, magazines, and conference proceedings on an item-by-item basis. In addition, the service will supply information from other publishers.

Rates for just about any article are US $10 for IEEE members and $12 for others. Orders for IEEE items received by noon Pacific time are shipped the same day. Articles from non-IEEE collections will cost slightly more.

The toll-free phone number in the United States and Canada for Ask*IEEE is 800-949-IEEE; for all other locations, 415-259-5040; fax, 415-259-5045. The Internet address is *askieee@ieee.org*.

Fellow nominations due April 15

All nominations for IEEE Fellows to be considered for election for 1994 are due at IEEE headquarters by April 15, 1993. Fellow nominating kits are available from the Staff Secretary, IEEE Fellow Committee, 345 E. 47th St., New York, N.Y. 10017; 212-705-7750; fax, 212-223-2911.

Coming
in Spectrum

KEEP IT CLEAN. Though the electronics industry is smokestack-free, the chemicals for cleaning circuit boards and for photoresists, and heavy metals and toxic gases have spawned environmental problems that are now being forcefully addressed.

FUZZY LOGIC II. Fuzzy logic has rapidly become one of the most successful of today's technologies for designing sophisticated control systems. This tutorial describes how adaptive control can be built into fuzzy systems.

PWM EXTENDS ITS SWAY. More powerful MOSFETs have made power amplifiers using pulse-width modulation (PWM) superior to linear dc types. Application areas include magnetic resonance imaging, canceling noise on ac power lines, and controlling magnetic bearings.

SCOPE WHIZZES. Analog oscilloscopes have lost more ground to the incredible speed of the latest digital breed. A major scope manufacturer tells the story.

LA SCIENCE ET LA GLOIRE. To become the high-technology leader in Europe, France has set up development centers that combine the efforts of government laboratories, private companies, and academia. Areas under attack include semiconductors, computers, software, transportation, and aerospace.

FAX FACTS. Perhaps none of the past decade's communication technologies has been so readily accepted and used as the digital facsimile machine. But this did not happen overnight—the first patent dates to 1843.

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